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Revision 1

Criticality Safety Evaluation for the OU 7-10 Glovebox Excavator Method Project

Paul J. Sentieri

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Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC

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ABSTRACT

This criticality safety evaluation provides documentation of an analysis of the potential for a nuclear criticality event and identifies controls required to prevent the postulated criticality event from occurring during execution of the Operable Unit 7-10 Glovebox Excavator Method Project. Specifically, the project plans were assessed to identify criticality controls related to the glovebox excavator method to ensure that a criticality hazard will not be likely under credible scenarios. The project will be implemented at the Subsurface Disposal Area of the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory.

The composition of the waste matrices expected to be retrieved and repackaged during the project supports the conclusion that the probability of a critical system forming is extremely unlikely. However, a criticality scenario can be postulated because no controls exist on the amount of fissile material present or on the introduction of moderating materials. Therefore, controls will be implemented that prohibit the disturbance of fissile-bearing waste material in the presence of an unsafe amount of moderator (e.g., water).

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ACRONYMS

CSE	criticality safety evaluation
DOE	U.S. Department of Energy
FGE	fissile gram equivalent
FMM	fissile material monitoring
HEPA	high-efficiency particulate air
IDC	item description code
INEEL	Idaho National Engineering and Environmental Laboratory
k_{eff}	effective multiplication factor
MCNP	Monte Carlo N-Particle Transport Code
OU	operable unit
PGS	Packaging Glovebox System
RFP	Rocky Flats Plant
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
WAC	waste acceptance criteria

Criticality Safety Evaluation for the OU 7-10 Glovebox Excavator Method Project

1. INTRODUCTION

1.1 Purpose

This criticality safety evaluation (CSE) documents an analysis of the potential for a nuclear criticality event and identifies controls required to prevent the postulated criticality event from occurring during execution of the Operable Unit (OU) 7-10 Glovebox Excavator Method Project. The project will be implemented at the Subsurface Disposal Area (SDA) within the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). The project is located within a small portion of OU 7-10 (Pit 9) of the SDA and the Transuranic Storage Area inside the RWMC. A map of the INEEL showing the location of the RWMC is provided in Figure 1. A graphic representation of the SDA showing an expanded view of the project area is provided in Figure 2.

1.2 Scope

The project plans were analyzed to identify criticality controls related to the glovebox excavator method to ensure that a criticality hazard is not likely under credible scenarios.

1.3 Background

The RWMC was established in the early 1950s as a disposal site for solid low-level waste generated by operations at the INEEL and other U.S. Department of Energy (DOE) laboratories. Radioactive waste materials were buried in underground pits, trenches, soil vault rows, and one aboveground pad (Pad A) at the SDA. Since 1970, transuranic waste has been kept in interim storage in containers on asphalt pads at the Transuranic Storage Area.

1.4 Objective

The objective of the project is to safely remove and containerize the buried alpha low-level mixed and transuranic waste from an area comprising a 20-ft radius by a 145-degree arc within OU 7-10. The boundary coordinates for the initial probe holes associated with this project are 40 to 80 ft north and 0 to 40 ft east of the southwest monument for a total area of 1,600 ft^2 (40×40 ft). The retrieval area is almost entirely encompassed within this space. The additional area is for use in the construction of a building that will enclose the working area. The majority of the waste buried in OU 7-10 consists of byproducts from the nuclear weapons program plutonium manufacturing process. Most of the original waste was containerized in 55-gal drums, $4 \times 4 \times 8$-ft wooden boxes, and smaller cardboard boxes.

The possibility of causing a criticality during the excavation and retrieval process does exist; however, the probability is extremely unlikely. Process knowledge and archived retrieval reports indicate that the integrity of the waste containers is in various stages of deterioration. The integrity of the containers may range from completely disintegrated to structurally sound.

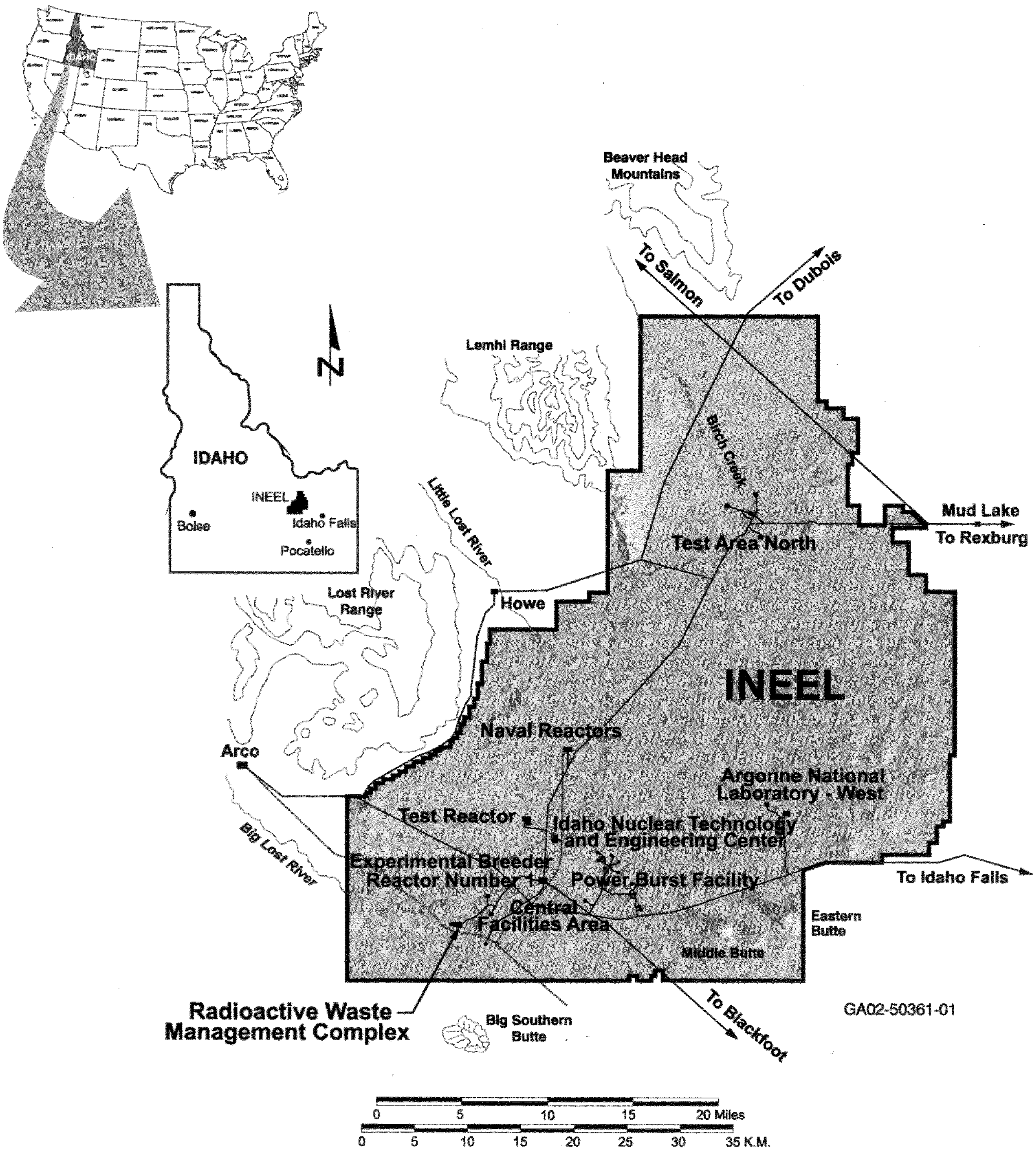

Figure 1. Map of the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory.

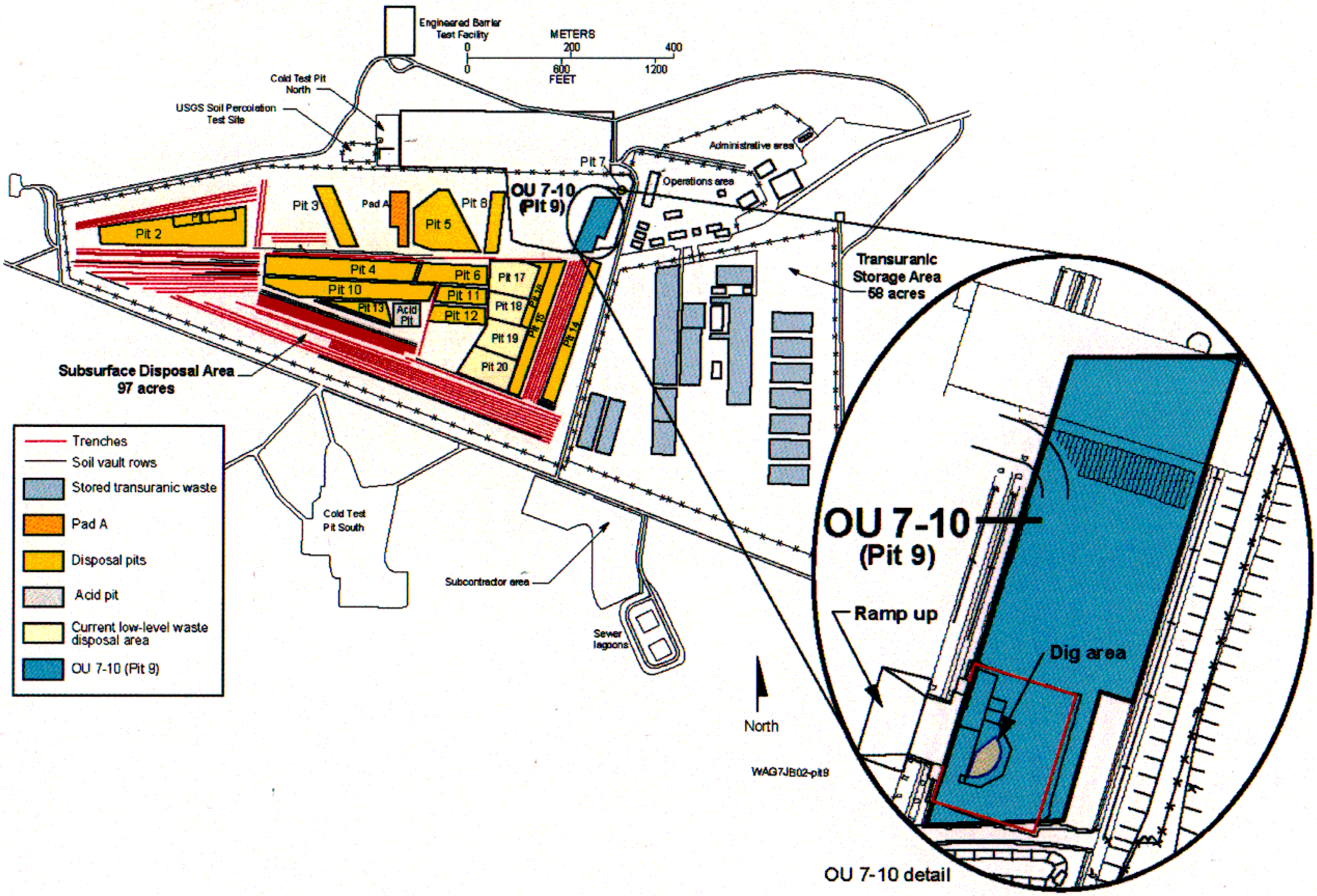

Figure 2. Graphic representation of the Subsurface Disposal Area showing an expanded view of the OU 7-10 Glovebox Excavator Method Project area.

Changing the waste environment (e.g., excavating and retrieving an overloaded drum that contains greater than 380 g of fissile mass) may increase the fissile mass density, increase moderation, or create a more favorable geometry for criticality. Changing one or all of these criticality parameters may increase the likelihood of a criticality accident within the project retrieval area. The criticality control parameters for the project are (1) moderation and (2) that the creation of a critical system is extremely unlikely even without controls because the parameters affecting criticality would need to be in near-optimum states. These parameters include the fissile masses necessary to achieve criticality in near-optimized geometry and concentration without the presence of diluent material or some mild neutronic absorbers.

The primary objective of the project is to remove and package 75 to 125 yd^3 of waste volume. The project design concept includes remote excavation, handling, and packaging of the retrieved waste from the retrieval area down to the underburden. The waste will be removed from the retrieval area in approximately 2 to 3-ft^3 loads, which is the capacity of the bucket that will be used on the backhoe excavator for the project. A simplified overview diagram for the project is illustrated in Figure 3. Further information on the details of the operation is contained in *OU 7-10 Glovebox Excavator Method Project Conceptual Design Report* (INEEL 2002a).

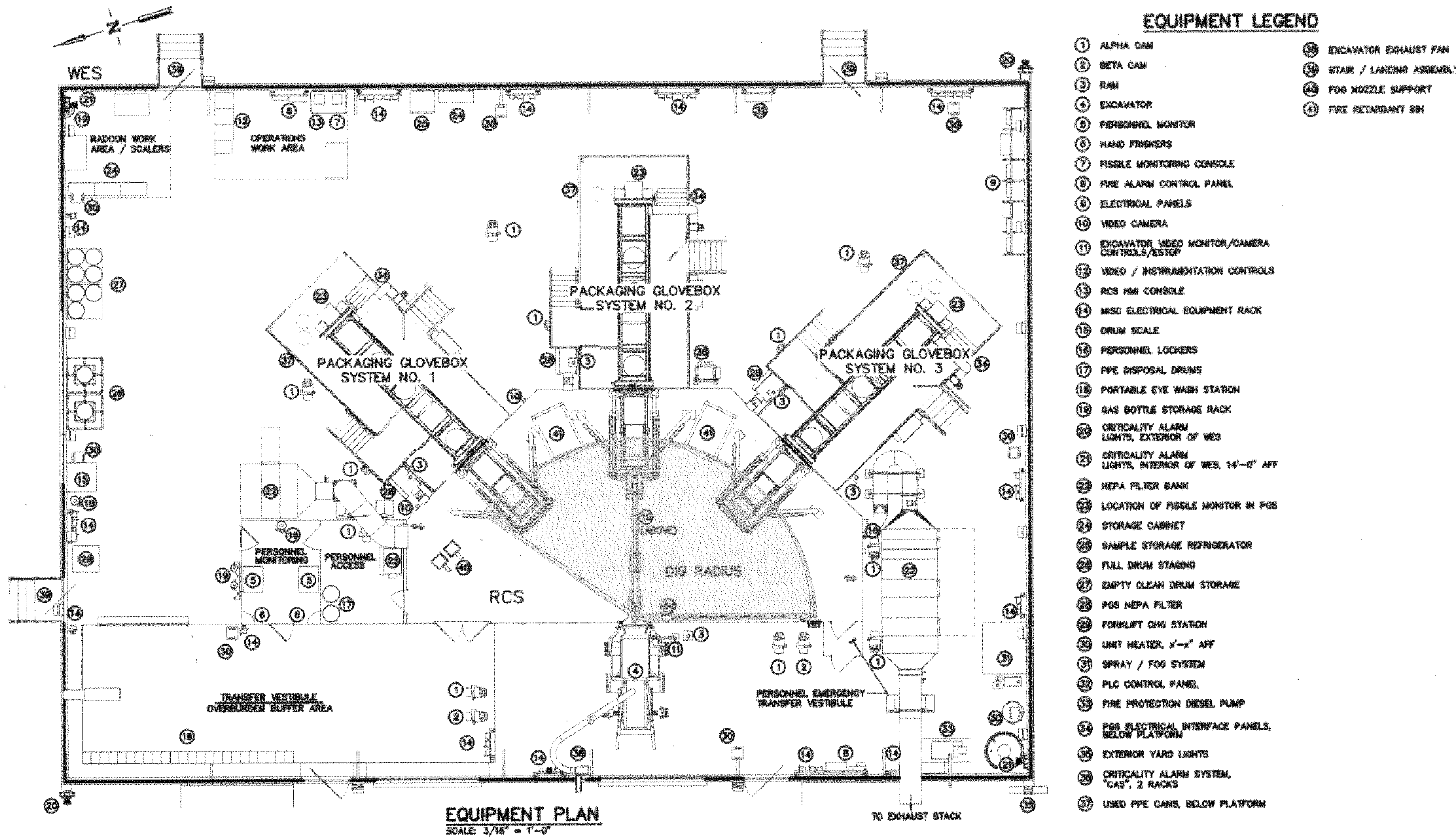

Figure 3. Simplified overview of the OU 7-10 Glovebox Excavator Method Project.

2. DESCRIPTION

In the following subsections, each process of the project is described in more detail as well as the criticality implications.

2.1 Waste Content

Studies have been performed to estimate the inventory of waste buried in OU 7-10. In a 1999 study,[a] R. W. Thomas examined shipping records, manifests, and trailer load lists of the waste that was discarded in the OU 7-10 site. Thomas identified 10 shipping records that coincide with the project location. He also concluded that only Rocky Flats Plant (RFP)[b] waste is buried in the 40 × 40-ft target area. Thomas estimated that 1,307 55-gal drums are located in the 40 × 40-ft project area. The taxonomy of the drums is given in Table 1, which also includes the content code that best describes the waste type and the recorded radionuclide inventory. The content codes and radionuclide inventory were taken from the *Content Code Assessment for INEL Contact-Handled Transuranic Waste* (Clements 1982). The mass given in the radionuclide inventory column is the estimated maximum amount, by mass (from the shipping records and manifests), that has been identified in any single drum within OU 7-10.

2.1.1 Plutonium

The plutonium in the project area consists of weapons-grade plutonium. The accuracy of the historical fissile-loading data cannot be relied on with total confidence. Recent assaying of drums received from the RFP, which are currently housed in aboveground storage, indicates that a very small percentage of drums exceed 200 g of fissile gram equivalent (FGE). Burial records indicate that waste material expected to be encountered in the waste retrieval area is composed of material that has not been associated with the overloaded drums in aboveground storage. However, these records do not mean that a drum that contains the expected waste materials could not be overloaded. In addition, the records do not exclude the possibility of encountering waste forms that are known to have higher fissile loading. This is based on assay results from aboveground storage operations.

To further estimate the maximum fissile mass buried in the project area, a comparison can be made between the overloaded drums identified at the RWMC and the expected waste drums contained in the project area. Currently, 36 overloaded drums (i.e., measuring greater than 380 g of fissile mass) are located at the RWMC in aboveground storage. A summary of the contents of the 36 overloaded drums, including the waste code of the suspect overloaded drums and the fissile mass, is provided in Table 2.

The comparison of the overloaded RWMC drums and the expected waste drums reveals that none of the expected drums in the project has the same content code as the overloaded drums. However, the conclusions based on this comparison do not guarantee that an overloaded drum of the expected waste

a. Thomas, R. W., Interdepartmental Memorandum to David E. Wilkins, April 16, 1999."Waste Contents Associated with OU 7-10 Stages I/II Activities in Pit 9," RWT-01-99, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

b. The Rocky Flats Plant is located 26 km (16 mi) northwest of Denver. In the mid 1990s the Rocky Flats Plant was renamed the Rocky Flats Plant Environmental Technology Site. In the late 1990s, it was renamed again to its current name, the Rocky Flats Plant Closure Project.

Table 1. Taxonomy of drums expected to be located during OU 7-10 Glovebox Excavator Method Project retrieval operations.

Number of Drums	Waste Type	Content Code	Radionuclide Inventory (g)	
379	Series 743 sludge	Code 3: Organic waste (e.g., degreasing agents, lathe coolant, and hydraulic oils).	Plutonium	16.0
260	Combustible material	Code 330: Waste consisting of dry combustible material (e.g., paper, rags, plastics, and surgeons' gloves).	Plutonium	45.0
42	Series 745 sludge	Code 5: Salt residue generated from concentrating and drying liquid waste from the solar evaporation ponds.	Plutonium	0.09[a]
28	Noncombustible material	Code 480: Nonline and line-generated metal waste (e.g., pumps, motors carts, and power tools).	Plutonium	129.0
27	Series 742 sludge	Code 2: Waste consisting of wet sludge produced from treatment of all other plant radioactive and chemical contaminated waste and further treatment of the first-stage effluent.	Plutonium	8.9
22	Graphite material	Code 300: Graphite molds generated by foundry operations and plutonium recovery operations.	Plutonium	61.0
3	Series 741 sludge	Code 1: Waste consisting of wet sludge produced from treating aqueous process waste (e.g., ion-exchange column effluent, distillates, and caustic scrub solutions).	Plutonium	157.0
2	Series 744 sludge	Code 4: Waste consisting of liquids adsorbed on a cement mixture.	Plutonium	22.7
544	Empty drums	No specific code: Suitable substitute codes may be 950 or 480.	Plutonium	129.0 [b]

a. Plutonium mass is the maximum amount of plutonium found in a drum in accordance with waste shipment records.
b. Plutonium mass is taken from the most conservative waste code (i.e., Content Code 480).

form will not be found, nor does it guarantee that an overloaded drum of an unexpected waste form will not be found.

As seen in Table 2, identified overloaded drums currently in aboveground retrievable storage at the RWMC fall into one of six content code descriptions. These categorizations are given in Table 3.

Table 2. Summary description of 36 overloaded drums identified at the Radioactive Waste Management Complex.

#	Drum Identification Number (bar code)	Waste Content Code	Plutonium Mass ± 1σ (g)	Plutonium Mass + σ (g)	Fissile Gram Equivalent Mass ± 1σ (g)	Fissile Gram Equivalent Mass + σ (g)
1	002336	393	913 ± 79	992	913 ± 79	992
2	002337	393	636 ± 53	689	636 ± 53	689
3	005636	393	911 ± 63	974	911 ± 79	974
4	006189	376	571 ± 60	631	571 ± 79	631
5	008850	376	422 ± 5	427	422 ± 79	427
6	009219	393	486 ± 57	543	486 ± 79	543
7	013320	376	1,046 ± 92	1,138	1,046 ± 79	1,138
8	013330	393	679 ± 87	766	679 ± 79	766
9	014340	409	269 ± 127	396	269 ± 79	396
10	014358	393	1,243 ± 117	1,360	1,243 ± 79	1,360
11	020948	393	481 ± 55	536	481 ± 79	536
12	023584	372	420 ± 42	462	420 ± 79	462
13	006175	409	460 ± 83	544	460 ± 79	544
14	012708	440	450 ± 132	582	479 ± 142	620
15	023886	376	622 ± 136	758	596 ± 130	726
16	028162	376	407 ± 147	554	385 ± 139	524
17	013232	376	410 ± 64	474	388 ± 61	449
18	016393	440	367 ± 109	476	347 ± 103	450
19	027567	376	838 ± 303	1,141	798 ± 288	1,086
20	021994	376	375 ± 74	449	355 ± 70	425
21	027560	376	388 ± 65	453	387 ± 61	448
22	021675	376	523 ± 180	703	495 ± 170	665
23	023600	376	465 ± 74	539	440 ± 70	510
24	027506	376	360 ± 75	435	341 ± 71	412
25	032893	376	1,672 ± 397	2,069	1,581 ± 376	1,957
26	033031	376	358 ± 81	439	338 ± 76	414
27	021015	376	433 ± 101	534	410 ± 95	505
28	009977	376	387 ± 61	448	366 ± 58	424
29	005823	376	373 ± 59	432	353 ± 56	409
30	022303	376	496 ± 77	573	496 ± 73	542
31	023283	376	289 ± 116	405	273 ± 109	382
32	008489	320	361 ± 133	494	363 ± 134	497
33	005648	376	401 ± 82	483	404 ± 82	486
34	006178	376	364 ± 84	448	379 ± 115	494
35	006196	376	384 ± 115	499	386 ± 115	501
36	006065	376	572 ± 140	712	575 ± 141	716

a. See Table 3 for corresponding item description code.

Table 3. Content code groupings.

Item Content Code	Description of Material
320	Tantalum—consists of heavy non stainless steel metals from process operations.
372	Grit—consists of grit (e.g., aluminum oxide and iron fines or pellets) used in grit-blasting operations.
376	Cemented insulation and filter media—consists of filter media removed from various filters, cement added to neutralize acids.
393	Sand/Slag and Crucible Heels – consists of insoluble residue or "heel" generated from processing magnesium oxide sand, slag and magnesium oxide crucibles contaminated with above discard limits.
409	Glass—consists of sample vials and laboratory glassware.
440	Molten salt—30% unpulverized, waste produced during molten salt extraction process, comprised mostly of chloride residues and plutonium and americium.

2.2 Retrieval Operations

Before the start of retrieval operations, a shoring box will be put in place to line the area (i.e., 20-ft radius by 145-degree arc). Using the shoring box will ensure that no additional overburden material will fall into the area during retrieval operations. A building will be constructed over the retrieval area called the Retrieval Confinement Structure. The Retrieval Confinement Structure will enclose the retrieval area and act as the confinement boundary during retrieval activities. These activities will have no impact on the criticality safety aspects of the area.

The overburden will be removed by a remote excavation system, which is essentially a backhoe excavator. The backhoe will be fitted with a modified bucket that has a volume capacity of approximately 2 to 3 ft^3. The volume of a 55-gal drum is approximately 7.6 ft^3. The removal of the overburden will be monitored from a radiological standpoint to ensure that the waste zone is not penetrated during this phase of the operation.

2.3 Bulk Waste Retrieval

The bulk waste will be removed from the project area with the aid of the excavator (shown in Figure 4). The excavator is a backhoe with changeable attachments for digging and retrieving the waste. If an unsafe amount of free liquid (defined as greater than 10 L) is visibly evident, then waste retrieval activities will stop until the free liquid is absorbed. However, large amounts of free liquids are not expected in the excavation area based on probing data. The excavator will place the waste zone material into a transfer cart. The transfer cart is essentially a tray to contain and transport the waste material. After the waste material is placed into the transfer cart, it will be moved into the Packaging Glovebox System (PGS). Once in the PGS, the waste will be segregated.

If the waste comprises soil, sludge, or visibly identifiable combustible materials that are known from process history to contain low fissile-loading waste, it will be placed directly into 55-gal drums without being fissile monitored in the PGS for fissile content. If the material being sorted in the PGS falls within any of the following categories, fissile monitoring will be required:

- Cemented high-efficiency particulate air (HEPA) filters
- High-efficiency particulate air filter media or intact HEPA filters
- Combustibles that cannot be distinguished from HEPA filter media
- Intact graphite molds and large chunks of graphite molds (defined as pieces larger than approximately 2 in. in diameter)
- Intact polyethylene bottles containing magnesium oxide
- Unidentified containerized waste that may contain unsafe amounts of plutonium.

Fissile monitoring will be performed before these waste forms are loaded into a drum. Readily identifiable noncombustible materials (e.g., primarily drum remnants and those materials shown to have low fissile loading through the use of process knowledge) will be allowed to be placed directly into waste drums without being subjected to fissile monitoring.

After the drums are loaded they will be placed into lag storage until assaying of the drum can be completed. Criticality separation distance of 16 in. will be maintained in the lag storage area between unassayed drums.

Intact drums uncovered in the waste retrieval area will be broken open in the bottom of the waste retrieval area in a drum-sizing tray. The purpose of this sizing is to ensure compliance with the 350 kg structural limit on the transfer cart. The drum demolition tray is shown in Figure 5.

2.3.1 Packaging Glovebox System

Three gloveboxes are attached to the Retrieval Confinement Structure (see Figure 6). Each glovebox will be constructed with a steel frame, fire resistant safety glass panels, glove ports with gloves and safety covers, access panels, a rail-mounted transfer cart, operator work platforms, and HEPA filter inlets for the ventilation system. Several packaging stations will be included in each glovebox for loading waste into 55- and 85-gal drums. Each packaging station will be accessed through a port in the bottom of the glovebox. A fissile material monitoring (FMM) system will quantify the fissile content of unknown and suspect items. It can be used to monitor drum loading of this material to ensure that fissile drum limits are not exceeded. Each glovebox will have a fissile monitoring system.

Waste material that has been retrieved will be sent to the PGS in transfer carts. The cart volume is large enough to contain one intact drum. However, the size of the excavator bucket will limit most loads to the volume of the excavator scoop or about one-third the volume of a 55-gal drum.

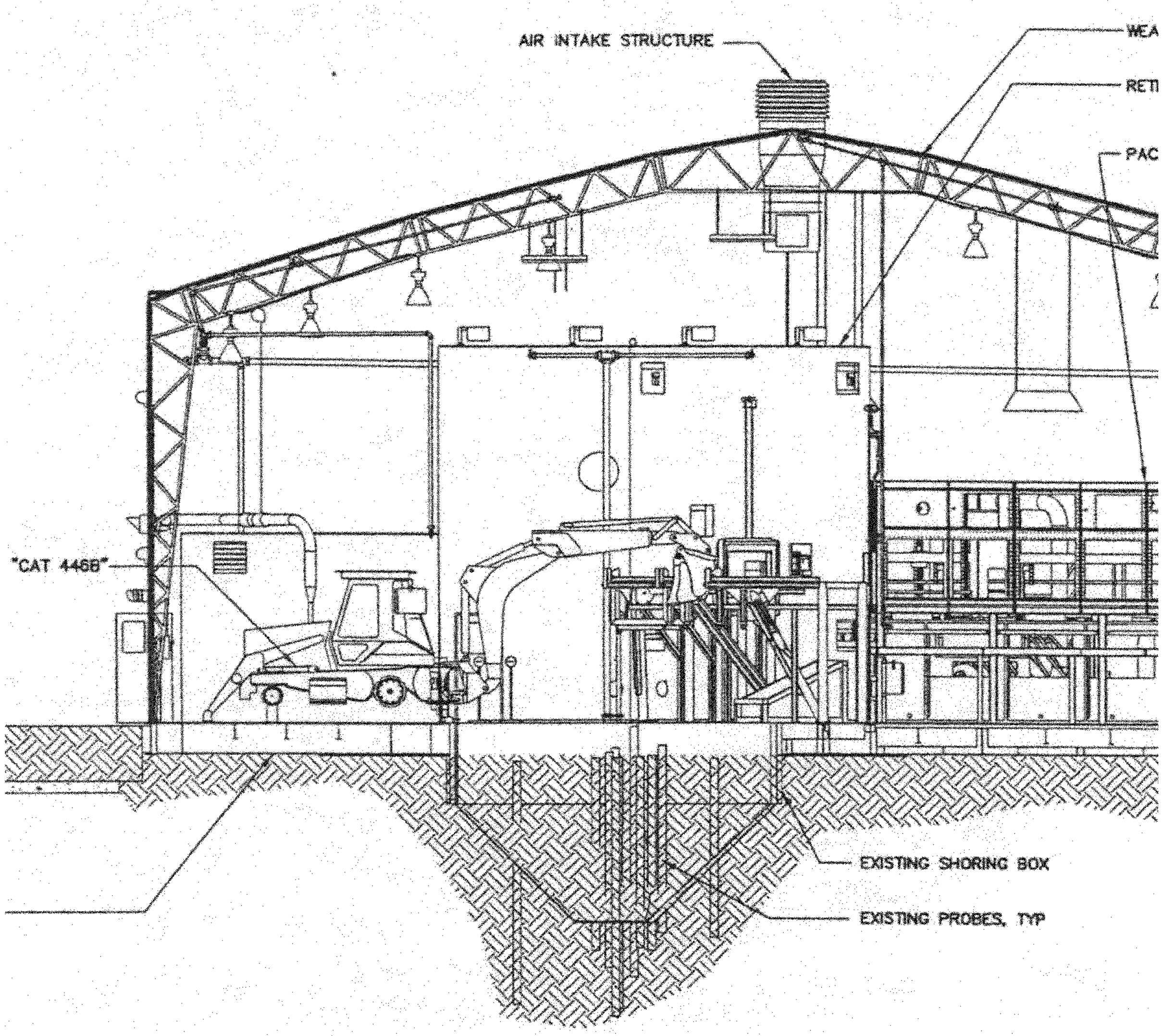

Figure 4. Diagram of excavator and glovebox for the OU 7-10 Glovebox Excavator Method Project.

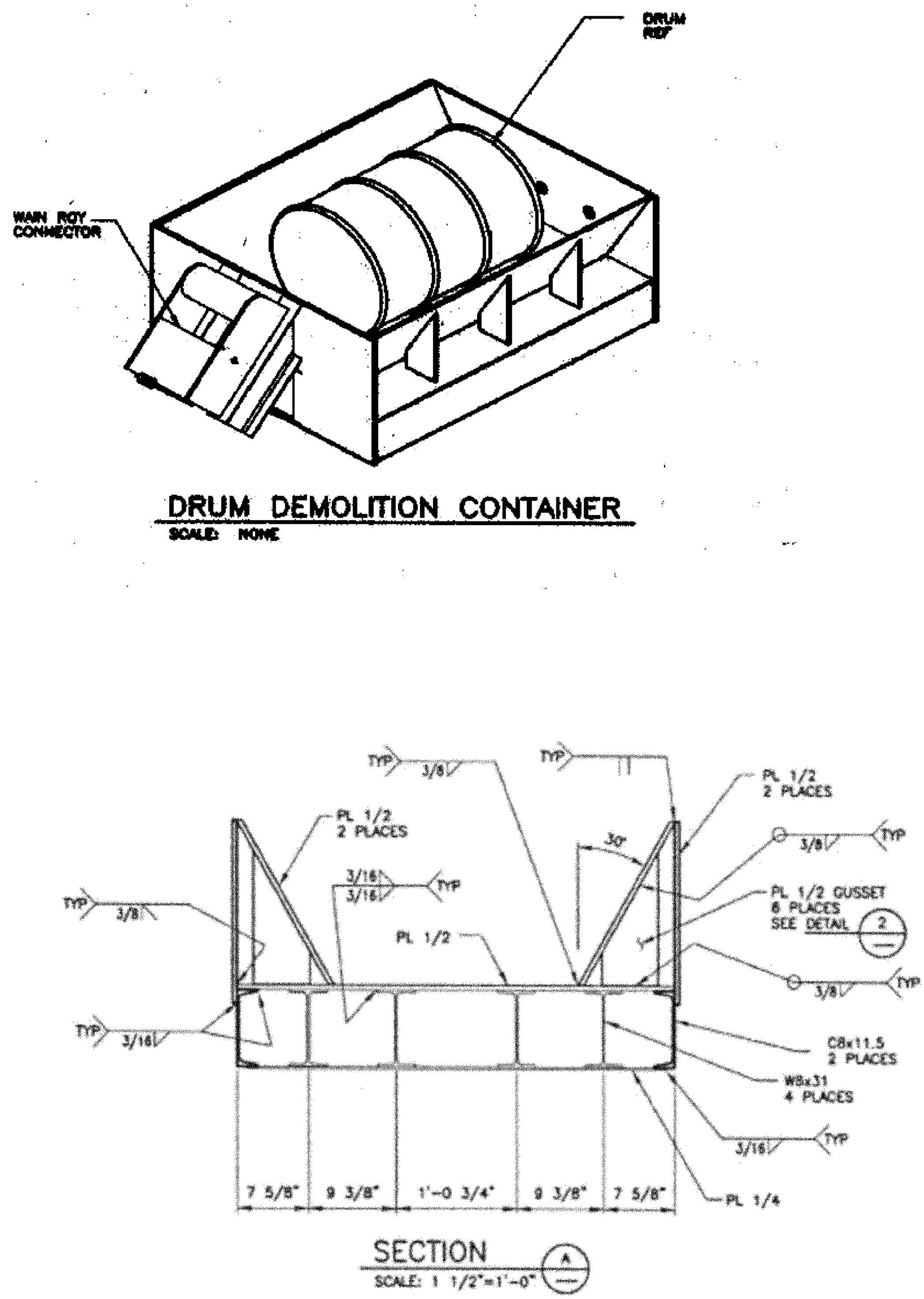

Figure 5. Diagram of drum sizing tray for the OU 7-10 Glovebox Excavator Method Project.

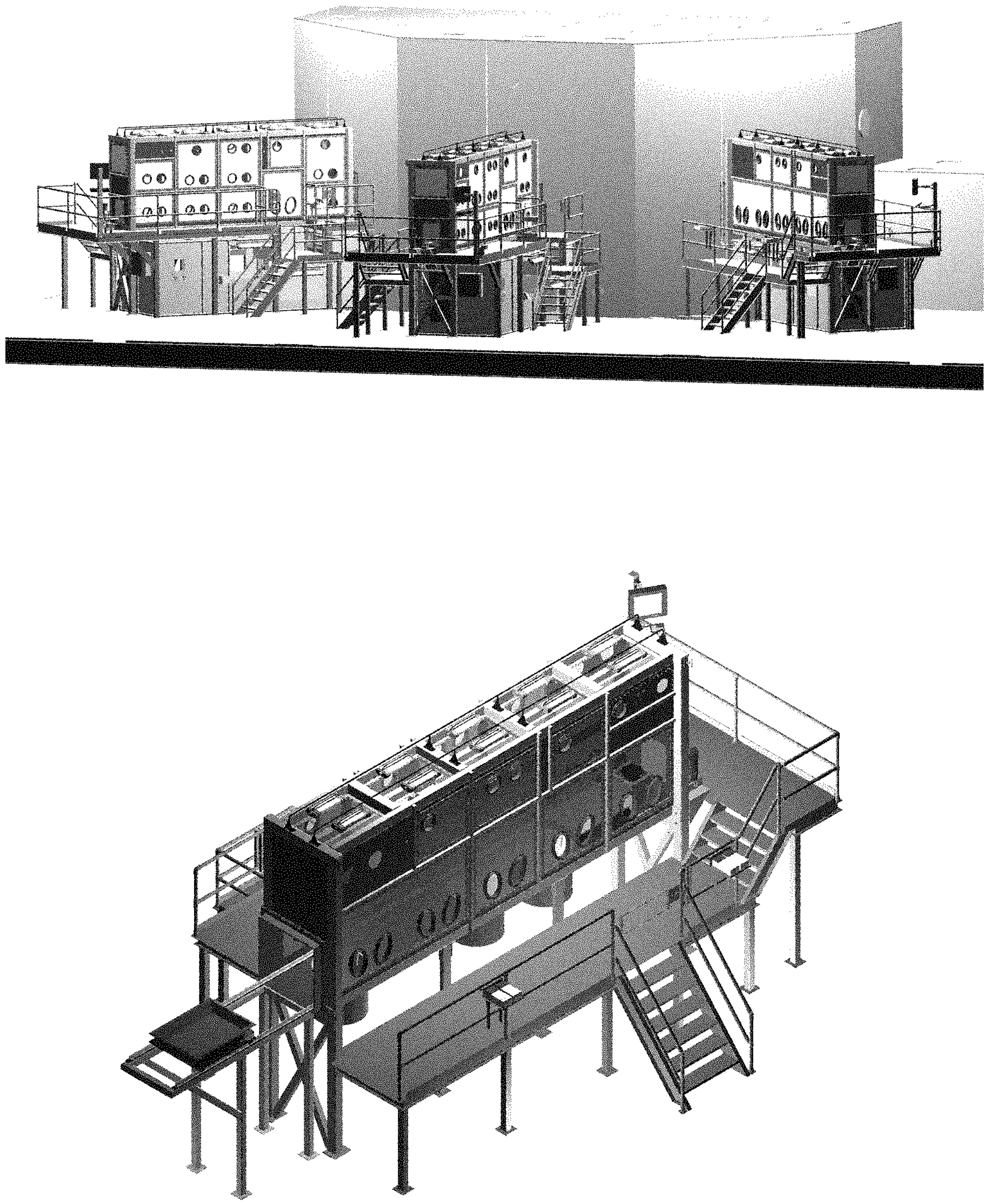

Figure 6. View of Packaging Glovebox System for the OU 7-10 Glovebox Excavator Method Project.

2.4 Material Evaluation in the Packaging Glovebox System

After the waste material has been transferred into the PGS with the transfer cart, an evaluation will be made of the type of material present. Materials of concern to criticality safety include cemented HEPA filters, filter media, intact HEPA filters, combustibles not distinguishable from HEPA filter media, and unknown containerized waste materials that could potentially contain unsafe plutonium masses. Other materials such as containers of magnesium oxide, intact graphite molds, and graphite pieces of molds that are larger than approximately 2 in. in diameter, need to be assayed based on past assay data and the historically higher fissile content in these waste forms. Based on past process knowledge, some waste matrices can be packaged directly into drums without monitoring the fissile content as the waste drums are being loaded. These materials include sludge, soils, and certain combustibles that can be readily identified as having low reactivity because of past process knowledge.

The fissile mass of other material (e.g., filter media, intact HEPA filters, and unidentifiable combustible material that could include some cellulose material) will require monitoring while these matrices are being loaded into waste drums. The monitoring will be performed to identify and prevent unsafe fissile masses from being loaded in a drum, which will ensure that the fissile loading limit per drum will not be exceeded. The creation of overloaded drums in this retrieval process is highly undesirable. Recovery from overloaded drums (drums containing more than 380 g FGE) containing the aforementioned waste material would require implementation of rigid controls that would prove difficult from an operational standpoint.

2.5 Lag Storage of Drums

Drums that contain waste matrices comprising sludge, soil, and certain identifiable combustible material will be loaded directly into drums without the fissile content being monitored in the PGS. However, these drums then will be stored in a lag storage area where the drums will be separated from other drums by a 40.64-cm (16-in.) edge-to-edge separation. This isolation will be in effect until the fissile content of the loaded drums can be determined by proper drum-assaying techniques.

2.6 Sampling

Current sample plans call for the collection of soil and sludge materials to accomplish confirmatory analyses relating to applicable material characterization requirements. The samples will be collected in 250-mL polyethylene bottles, which equates to approximately 380 g of soil, assuming a soil density of 1.46 g/cm^3. Based on the sample sizes that will be taken, waste matrix being sampled, no criticality concern is expected during sampling activities, and no criticality controls will be implemented because of sample handling.

3. REQUIREMENTS DOCUMENTATION

No special requirements are applicable to this CSE.

4. METHODOLOGY

Calculational models were developed for this evaluation. These calculations use the Monte Carlo N-Particle Transport Code (MCNP) computer program (RSIC 1997) to assess the criticality potential associated with OU 7-10 Glovebox Excavator Method Project activities. The MCNP program and the validation of the MCNP code are described in this section.

4.1 Description of Method

MCNP is a general-purpose code for calculating the time-dependent continuous-energy transport of neutrons, photons, and electrons in three-dimensional geometries. The MCNP code is used for many applications (e.g., nuclear criticality safety, radiation shielding, fission heating, and many other nuclear-related topics). This code was used in this analysis to determine the calculated effective multiplication factor (k_{eff}). The k_{eff} is a measure of a finite system's ability to sustain a nuclear chain reaction and is defined with the following criteria:

- Supercritical if $k > 1$
- Critical if $k = 1$
- Subcritical if $k < 1$.

The MCNP program was performed on a Hewlett-Packard Series 9000 workstation using the HP-UNIX 10.20 operating system. The MCNP-4b2 used the ENDF/B-V cross-section data to calculate the results. The workstations are verified and validated in accordance with the INEEL *Software Quality Assurance Plan for MCNP4A and MCNP4B2* (Montierth 2000).

The analyzed system contained in this report consisted of plutonium dispersed in various waste matrices including soil, graphite, and magnesium oxide. The geometry of the systems evaluated consisted of waste materials and plutonium in cylindrical form (drums), spherical form (optimized systems), and rectangular form (transfer cart).

No critical experiments exist that exactly match the types of systems evaluated. However, modeling critical experiments encompassing the parameters evaluated can validate the various models. These parameters include material composition, moderation conditions, reflection conditions, and spectral neutron energy ranges.

Validation for these calculations requires experiments consisting of moderated plutonium solution systems and plutonium combined with silicon and graphite.

A separate report was completed that evaluated critical plutonium/silicon configurations.[c] Experiments consisting of plutonium fuel rods intermixed in a triangular lattice with silicon/dioxide rods, were performed in Obninsk, Russia in 1998 and 1999. A complete detailed description of the critical configurations can be found in Tsiboulia (2000).

A brief description of the experiments follows. Ten different types of rods were used in the plutonium experiments. Each of the rods consisted of a stack of various discs or pellets of various materials. These materials included plutonium metal canned in stainless steel, silica pellets, polyethylene pellets, stainless steel pellets, and boron carbide pellets. Each of the 10 different rods contained a

c. This report, completed in 2002 by J. W. Nielsen, concerned validation of uranium and plutonium silicon dioxide experiments.

combination of these pellets in a stacked configuration. The rods were then combined to create a critical system. The fuel tubes were arranged in a hexagonal array with a 5.1-cm pitch.

The experiments were modeled as described above. The calculated results for the experiments using the ENDF/B-V cross section library are provided in Table 4. The H/X ratio and Si/X ratio for the experiments is also presented in the table. The H/X ratio varied from 0 to 35 while the Si/X ratio varied from 23 to 42. The calculated neutron energy spectrum for these experiments indicates that the energy of the neutrons causing fission is primarily in the intermediate range (0.625 eV to 100 keV) to fast (more than 100 keV). The average calculated k_{eff} for these experiments is 1.0075 ± 0.0003.

Table 4. Calculated results for the uranium experiments.

Case Name	H/X	Si/Pu	$k_{eff} \pm \sigma$
BFS-81/1	0	23.4	1.0001 ± 0.0006
BFS-81/1A	0	23.4	0.9987 ± 0.0008
BFS-81/2	2.8	23.4	1.0055 ± 0.0008
BFS-81/3	5.6	23.4	1.0089 ± 0.0008
BFS-81/4	35.2	41.6	1.0178 ± 0.0008
BFS-81/5	35.2	41.6	1.0164 ± 0.0008
Average: $k_{avg} = \Sigma (k_i/\sigma_i^2)/ \Sigma (1/\sigma_i^2)$, $\sigma_{avg} = (1/ \Sigma (1/\sigma_i^2))^{½}$			1.075 ± 0.0003

The performance of this code package and computational platform is well demonstrated for plutonium solution systems. Two cases were modeled that consisted of plutonium nitrate in a bare and reflected spherical configuration. A complete description of these cases can be found in Carter (1999). The MCNP listings associated with these cases can be found in Appendix A of this report.

The first case evaluated consisted of a 19.608-cm (15.2-in.) diameter radius spherical shell containing plutonium nitrate. The thickness of the 304-L stainless steel shell is 0.1219 cm (0.048 in.). The spherical shell in this case was not reflected. The plutonium nitrate solution had a concentration of 39.0 g/L plutonium. The H/Pu ratio was approximately 700 for this case. The calculated $k_{eff} \pm 1\sigma$ for this case was 1.0134 ± 0.0013.

The second case evaluated consisted of the same spherical configuration except this case was reflected by a 30.0-cm (11.81-in.) water reflector. In this case the concentration of the plutonium nitrate was 25.2 g/L plutonium, with the sphere being full to a height of 18.754 (7.31 in.) cm above the centerline of the sphere. The H/Pu ratio was approximately 1,100 for this case. The calculated $k_{eff} \pm 1\sigma$ for this case was 1.0154 ± 0.0010.

The last set of cases that were evaluated consisted of PuO_2/polystyrene and reflected by plexiglass. Experiments were performed at Hanford between 1963 and 1970. The experiments consisted of cubes of PuO_2/polystyrene reflected by plexiglass plates. Twenty-nine experiments were performed with various configurations, concentrations of plutonium and plutonium enrichments.

The cubes were approximately $2 \times 2 \times 2$ in. The cubes were stacked on a split table critical assembly. The two halves of the assembly were brought together and the neutron multiplication determined using proportional counters. Some of the cubes were cut in the axial direction to allow flexibility in obtaining a critical height. The final critical configuration consists of a rectangular block of $PuO_{2/}$polystyrene reflected on all six sides by plexiglass. The H/Pu ratios ranged from 5.87 to 65.4 with the C/Pu ratios varying from 5.86 to 64.4. A more detailed description of these experiments can be found in an internal report by J. W. Nielsen that discusses validation of calculations containing HEU/graphite and Pu/polystyrene. The results from these cases can be found in Table 5.

Table 5. Calculated results for the PuO_2/polystyrene experiments.

Case Name	$k_{eff} \pm \sigma$
Case 6	1.0170 ± 0.0009
Case 7	1.0177 ± 0.0008
Case 8	1.0173 ± 0.0007
Case 9	1.0193 ± 0.0008
Case 10	1.0285 ± 0.0010
Case11	1.0270 ± 0.0010
Case 12	1.0247 ± 0.0010
Case 13	1.0233 ± 0.0009
Case 14	1.0275 ± 0.0010
Case 15	1.0256 ± 0.0009
Case 16	1.0214 ± 0.0010
Case 17	1.0045 ± 0.0009
Case 18	1.0088 ± 0.0008
Case 19	1.0051 ± 0.0007
Case 20	1.0056 ± 0.0008
Case 21	1.0072 ± 0.0009
Case 22	1.0101 ± 0.0008
Case 23	1.0054 ± 0.0009
Case 24	1.0054 ± 0.0008
Case 25	1.0069 ± 0.0017
Case 26	1.0081 ± 0.0009
Case 27	1.0086 ± 0.0008
Case 28	1.0091 ± 0.0009
Case 29	1.0110 ± 0.0010
Average: $k_{avg} = \Sigma (k_i/\sigma_i^2) / \Sigma (1/\sigma_i^2)$, $\sigma_{avg} = (1/ \Sigma (1/\sigma_i^2))^{1/2}$	1.0139 ± 0.0002

As shown by the results of these validation experiments, no bias caused by calculational methodology is warranted.

5. DISCUSSION OF CONTINGENCIES

The double contingency principle as stated in DOE Order 420.1, "Facility Safety," is defined below.

> The double contingency principle shall be used as a minimum to ensure that a criticality accident is an extremely unlikely event. Compliance with the double contingency principle requires that two unlikely, independent, and concurrent changes in process or system conditions occur before a criticality accident is possible.

Consideration has been given to project scenarios that could have an impact on criticality safety. The requirements of the double contingency principle have been met for those proposed operations in this project and the project is covered under a formal safety analysis basis. Reliance on administrative controls will be adequate because such a large margin of safety is inherent in these types of waste systems, which by the nature of the waste material would make achieving a critical state extremely unlikely.

5.1 Waste Retrieval Operations

Contingency analysis for the digface surface area maintains criticality safety by controlling operations in the presence of an unsafe amount of moderating material. Table 6 contains the contingencies for waste retrieval operations.

Table 6. Contingencies for waste retrieval operations.

Scenario Number	Scenario Description	Failure or Barrier	Additional Information
1	Excavation of an overloaded drum while an amount of moderating material (e.g., water) greater than 10 L is present.	(1) Violation of administrative controls prohibiting retrieval operations if greater than 10 L (2.6 gal) of free liquids are encountered during digging operations. (2) Achievement of a favorable criticality configuration that is required to form a critical system.	Conditions that are required for a criticality to occur include sufficient mass, optimal moderation, favorable geometry, and insufficient diluent in the waste.
2	Activation of the deluge system either manually or through failure of a valve during excavation operations when an unsafe amount of fissile material is disturbed.	(1) Violation of administrative controls prohibiting retrieval operations if more than 10 L (2.6 L) of free liquids are encountered during digging operations. (2) Achievement of a favorable criticality configuration that is required to form a critical system.	Conditions that are required for a criticality to occur include sufficient mass, optimal moderation, favorable geometry, and insufficient diluent in the waste.

5.2 Packaging Glovebox System

Contingency analysis for the PGS contains criticality safety margins that are maintained by controlling operations in the presence of an unsafe amount of moderating material and limiting the fissile mass placed into a waste drum for certain waste matrices through the process of monitoring (see Table 7).

Table 7. Contingencies for the Packaging Glovebox System.

Scenario Number	Scenario Description	Failure or Barrier	Additional Information
1	Excavation of an overloaded drum brought into the PGS that contains waste forms of concern.	(1) Failure to monitor fissile mass of waste material of concern as it is loaded into the waste package (2) Violation of administrative controls prohibiting operations in the PGS if greater than 10 L (2.6 gal) of free liquids is encountered in the PGS.	Introduction of unsafe amounts of moderating material through activation of the PGS fire suppression system Conditions that are required for a criticality to occur include sufficient mass, optimal moderation, favorable geometry, and insufficient diluent in the waste.

PGS = Packaging Glovebox System

6. EVALUATION AND RESULTS

The methods of criticality control evaluated for the OU 7-10 Glovebox Excavator Method Project are outlined in the following sections and the results from the analysis are presented. The corresponding computational model listings used in support of this analysis are presented in Appendix A.

6.1 Assumptions

Assumptions used in the analysis are listed below:

- The amount of fissile mass present is not known with complete certainty
- The geometry, as a condition of the fissile system, cannot be controlled in the waste retrieval area
- Fire in the PGS is an anticipated event.

As stated previously, the fissile content within the excavation area has been estimated to be low but some uncertainty with these estimates and the records supporting these estimates exist. Therefore, an underlying assumption is that the fissile content in the excavation area is not known with certainty.

Additionally, the condition of the containers that held the fissile material is expected to be in a degraded state. Therefore, the containers cannot be relied upon to provide geometrical configuration control for the fissile material.

The third assumption, which is conservative, is stated in the final documented safety analysis as an anticipated event. The pyrophoric nature of some compounds in the waste, along with the combustible material loading and uncertainties in the waste, leads to this conclusion.

6.2 Criticality Control

The criticality control philosophy for the project is taken from ANSI/ANS-8.1, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors" (ANSI 1998). The nuclear criticality standard (ANSI 1998) designates criticality control by geometry (e.g., passive engineered controls) as the preferred method. An example of geometrical control is the limited height of the transfer cart. In situations where control by geometry is not practical, control by administrative measures may be considered. In addition, the design and operation of facilities that process material outside of reactors must follow the double contingency principle described in ANSI/ANS-8.1 (ANSI 1998). In accordance with the double contingency principle, two separate, independent, and unlikely changes in process or system conditions are required before a criticality accident can occur.

Criticality concerns associated with these operations include encountering an overloaded drum in the waste retrieval area. The control associated with this concern will be to not allow the disturbance of material in the waste zone in the presence of more than 10 L (2.6 gal)of free liquid.

A similar concern will exist in the PGS system should an unsafe fissile mass be brought into the PGS from the waste retrieval area. A similar control is associated with operations within the PGS. This control will stop operations and will not allow further processing of waste material within the glovebox if more than 10 L (2.6 gal) of free liquid is present. Before operations are resumed, the free liquids must be absorbed or removed from the system.

Another criticality concern associated with this operation includes the placement of an unsafe fissile mass into a waste drum in the presence of certain waste forms. Certain waste forms (e.g., HEPA filter media) could have potentially high-fissile loading. The physical form of the waste (if placed directly into a drum without knowing the fissile content) could lend itself to creating an unsafe condition in which the addition of moderating material could lead to a postulated critical configuration. Because moderator (e.g., water) will not be excluded from the glovebox, certain waste forms will be required to be fissile monitored and the fissile material will be tracked as the drum is filled. This will control the amount of material present in the drum for these certain waste matrices, thus precluding a critical system from forming in the event of flooding.

6.3 Process Areas

The process areas are broken into the three distinct areas listed below:

- Waste retrieval area
- Packaging Glovebox System
- Drum storage area.

Each of these areas and the associated criticality controls are discussed in more detail in the following subsections.

The various parameters that influence whether a system can achieve a critical state are listed below:

- Presence of fissile mass
- Presence of moderator
- Geometrical configurations
- Presence of diluents or neutronic absorbers
- Reflection conditions surrounding the systems
- Concentration of fissile material and nature of their distribution in the system.

Most of these factors would require optimization in some combination to achieve a critical system that is constructed within reasonable constraints. As a deviation from optimum conditions occurs, the reactivity of the systems decreases dramatically. In addition, as previously stated, an unsafe amount of moderator would be necessary to form a critical system in these waste forms.

Of these parameters, the presence of fissile mass in the waste retrieval area, along with the existing geometry of the material, is not controllable. The fissile system may be reflected because this system would exist within soil. Diluent materials that also act as neutronic absorbers are known to exist in the waste material. The quantity and distribution of these materials cannot always be relied on to guarantee that the system will remain in a subcritical state. However, in every case, an unsafe amount of moderator would be required to achieve a critical system.

The expected fissile mass associated with most of the expected waste forms in the waste retrieval area is low (i.e., less than 200 g FGE per buried drum). However, this does not exclude the possibility of an area of higher fissile mass within the waste retrieval area.

6.4 Waste Retrieval Operations

6.4.1 Waste Retrieval Operations Area

Disturbing an overloaded drum and creating an unfavorable configuration during the excavation and retrieval process is possible. Process knowledge, archived retrieval reports, and visual probes indicate that the waste containers are in various stages of deterioration. The integrity of the containers may range from being completely disintegrated to structurally sound. Changing the waste environment (i.e., excavating and retrieving the waste) may optimize the fissile mass density, increase moderation, or create a more favorable geometry for a criticality hazard. Changing one or all of these criticality parameters may increase the likelihood of a criticality accident at the waste retrieval surface.

The nature of the waste configuration limits the controls that can be set. Moderator controls can be implemented during retrieval operations. Moderating material in sufficient amounts to create a near optimally moderated system would be necessary to postulate a critical configuration. Moderator could be introduced into the system during the waste retrieval process by (1) uncovering an intact waste package or intact plastic bag that contains an unsafe amount of free liquid or (2) the activation of the deluge fire protection system. In either of these scenarios, the introduction of moderating material in an unsafe amount would be required along with the disturbance of an unsafe amount of fissile material to create a configuration that could be postulated as critical. However, even in the presence of an unsafe fissile mass with moderator, creating the near-optimum conditions required to form a critical system will be extremely unlikely.

The plutonium is in an oxide form as PuO_2. To achieve a critical system with the minimum mass of PuO_2, the system must be optimally moderated. The closer the system is to the optimum moderation range, the closer it is to the minimum critical mass. A single parameter limit for volume is given in ANSI/ANS-8.1 for systems comprised of plutonium nitrate ($Pu[NO_3]_4$) in which the Pu-240 is greater than or equal to 5 wt%. This limit is given as 10 L (2.6 gal). This volume takes credit for the nitrate, which is a mild neutron absorber. This value is conservative to use as a volumetric limit, even though the expected fissile material form within the retrieval area is PuO_2. Theoretically, a critical configuration could be formed with a slightly smaller amount of liquid when combined with PuO_2 as opposed to $Pu[NO_3]_4$. Using the volumetric limit associated with plutonium nitrate is conservative because of (1) the actual diluteness of the plutonium oxide throughout the expected waste matrices, (2) the many other mild neutronic absorbers and diluents within the waste constituents that would be mixed with the plutonium, and (3) the actual configuration of the plutonium oxide in the retrieval area is not in an ordered geometrical configuration. For the purpose of this effort, this volumetric limit can be applied as the amount that constitutes an unsafe amount of moderating material (i.e., free liquid) introduced into the system. The systems evaluated in this CSE consist mainly of PuO_2 combined with various matrices, including water.

A critical system can be formed with dry oxide material but the fissile mass necessary to achieve a criticality is quite large. The subcritical limit for PuO_2 systems that contain no more than 1.5 wt% water is given as 11.5 kg of PuO_2 containing 10.2 kg of the fissile isotope Pu-239 (LANL 1996). In dry systems consisting of larger fissile masses (e.g., very near the critical limit), a small amount of moderating material could cause the system to go from a safe to an unsafe condition. The expected lower localized fissile masses in the operation indicate that a larger volume of moderating material would be necessary to achieve an unsafe condition. The volumetric limit of 10 L (2.6 gal) also assumes optimum geometry, optimum homogeneous concentration, and full reflection. The first two conditions are idealized and will not be encountered in this retrieval operation. Additionally, the close-fitting full reflector around the system is also conservative.

6.4.2 Results

Criticality prevention during waste retrieval will use administrative controls that prohibit operations while an unsafe amount of moderator is present. By stopping operations when moderator is present, formation of a criticality hazard will be extremely unlikely.

Scenarios were examined for flooding of the pit and a conclusion was reached that additional water would not pose a criticality hazard for existing material in its current form and configuration because of the form and distribution of the fissile material and the presence of diluents in the current configurations (Sentieri 2002). However, the possibility of the introduction of moderator in the presence of an unsafe amount of fissile material being disturbed during excavation operations cannot be dismissed. A control can be implemented that prohibits excavation operations in the presence of an unsafe amount of moderating material, in this case greater than 10 L (2.6 gal) of free liquid. This limitation would prevent the creation of an unfavorable geometrical configuration by creating a more homogenous mixture of possible fissile material present and the unsafe amount of moderating material.

Previous criticality studies have been conducted that determined the effects associated with the addition of water in expected configurations and arrays of fissile material. The *Criticality Safety Study of the Subsurface Disposal Area for Operable Unit 7-13/14* (Sentieri 2002) shows the large amounts of fissile mass or the ordered arrangements of fissile mass necessary to postulate a critical configuration. In addition, OU 7-10 has been flooded on more than one occasion with no evidence of a criticality occurrence.

Fissile material is not anticipated to accumulate or preferentially concentrate in the waste retrieval area. However, the one area where fissile material may accumulate beyond the expected contamination levels is on the filters of the ventilation system. Fissile material may become airborne and accumulate with other nonfissile dust particles on the filters. The Radiation Control group will periodically monitor the filters. The filters will be monitored for radiation fields and pressure differential to ensure material buildup is not occurring. At this point, fissile accumulation on the filters is not anticipated to pose a criticality hazard because no mechanism is in place to preferentially concentrate only the plutonium particles on the filters.

6.5 Packaging Glovebox System

The PGS design is finalized. Appropriate design provisions or other criticality controls to ensure criticality safety are identified in this CSE.

A fire suppression system exists in the PGS and the major criticality safety concern would be the introduction of an unsafe amount of moderator in the presence of an unsafe amount of fissile material. The frequency of fires that would necessitate activation of the fire suppression system in the PGS has been documented in the *Preliminary Documented Safety Analysis for the OU 7-10 Glovebox Excavator Method Project* (INEEL 2002b). This frequency was determined to be an anticipated abnormal event.

In addition, creating an overloaded drum during this retrieval process is not desirable. This is especially true for certain types of waste that would require moderator exclusion while the drums are being repacked. The need for moderator exclusion would be necessary for drums containing waste material with higher void volume fractions and could be postulated to have a reactive configuration of PuO_2 if the drums were to become moderated. These waste types include HEPA-filter media, intact HEPA filters, and unidentifiable combustible material that may include some cellulose material.

The FMM system will be used to estimate the fissile loading of small batches of waste material identified as needing fissile monitoring. The FMM system will consist of the detector assembly, data acquisition system or microprocessor, and the operators control assembly.

The waste material to be monitored will be placed into a 5-gal specimen container. The 5-gal container will contain drain holes approximately 5 in. from the container bottom to ensure not more than 10 L (2.6 gal) can be accumulated in the container. This container then will be placed into the monitoring station. The monitoring station is housed at the floor level of the glovebox. It is surrounded on three sides by a 2-in. thick shield. The shielding does not form a watertight seal, thus allowing water to drain out of the monitoring station into the glovebox proper. The detector will be placed outside of the glovebox. This detector will monitor the fissile material through a window.

For the purposes of this evaluation the PGS will be divided into three operational areas: the transfer cart, the glovebox, and the drum loadout stations. These three areas will be evaluated from a criticality safety standpoint.

6.5.1 Transfer Cart

The transfer cart is the method that will be used to transport fissile material into the PGS for evaluation, examination for specific waste matrices, and eventual placement into drums.

The design of the transfer cart is a rectangular tray (see Figure 7), which is 7 in. deep, 30 in. wide, and 42 in. long. The calculational model evaluated a cart that was 8 in. in depth by 50 in. in width by 62 in. in length. The cart was evaluated at this size to envelope manufacturing tolerances and also encompass the dimensions of the drum-sizing tray.

Calculations were performed for various concentrations of PuO_2 distributed in saturated soil. The results of these calculational models are given in Table 8, which are within the acceptance criterion of $k_{eff} + 2\sigma \leq 0.95$. The calculational model evaluated the transfer cart filled with varying solutions of PuO_2 in fully saturated soil with three reflector conditions, which are (1) not reflected, (2) fully reflected by water, and (3) fully reflected by saturated soil. In these cases the fissile material was conservatively distributed homogeneously through the entire volume of the transfer cart at the stated concentration.

Table 8. Results from transfer cart calculational models.

Reflector Condition	PuO_2 in Saturated Soil (g/L)	Pu-239 in Transfer Cart (g)	$k_{eff} + 2\sigma$
Soil	15	5108	0.869
Water	15	5108	0.844
None	100	34,052	0.738

As shown by the results in Table 8, a rather large quantity of fissile material is required to achieve an unsafe condition. One of the factors affecting this is the geometry of the transfer cart. The rather shallow design of the cart allows for neutron leakage, which increases the fissile mass necessary to create an unsafe condition. As expected, a large mass of fissile material combined with soil in a homogenous fashion would be necessary to achieve an unsafe condition.

In most cases, a system of fissile material and water would be more reactive thus requiring a smaller fissile mass to formulate an unsafe condition A case was modeled that consisted of

15 g/L of PuO_2, combined with water within the volume of the transfer cart. This system was fully reflected on all sides by full-density water. The result of this model yielded a $k_{eff} + 2\sigma = 0.945$, with 5,108 g of Pu-239 in the system. As shown by this case, a PuO_2-water system is more reactive than the PuO_2-soil system; therefore, a lower concentration exceeds the acceptance criterion. However, even for such an idealized system, a large fissile mass is necessary to achieve an unsafe condition in the geometrical configuration of the transfer cart.

These results show that for a criticality to occur in the transfer cart, a large homogeneously distributed fissile mass must be present along with full flooding. Additionally, the system must be free from neutronic diluents and absorbers in a near optimally moderated configuration surrounded by full reflection. The assumptions used in these models are extremely conservative. The combination of these events is deemed not credible.

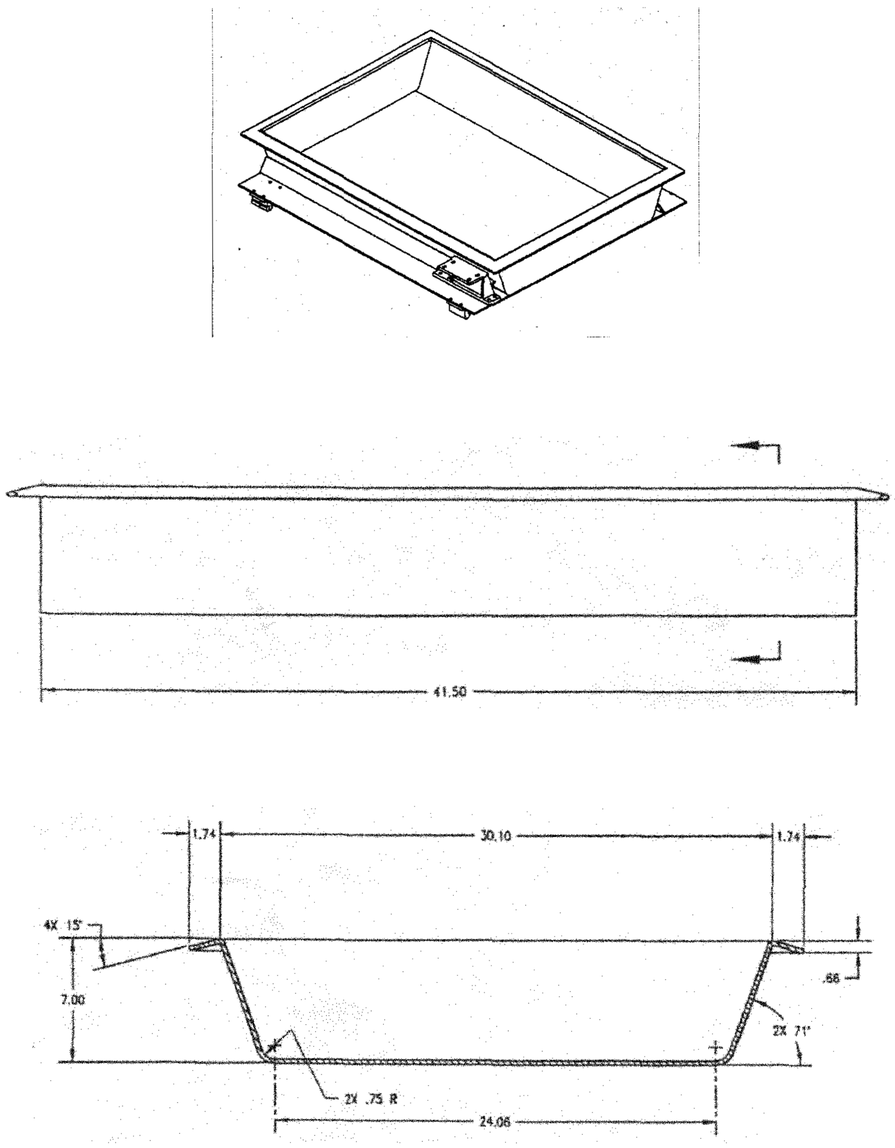

Figure 7. Diagrams of the transfer cart for the OU 7-10 Glovebox Excavator Method Project.

6.5.2 Glovebox

Operations in the glovebox involve the following activities:

- Sorting and evaluating material in the transfer cart
- Fissile monitoring those suspect matrices
- Obtaining necessary samples
- Preparing material for placement into the waste drums.

Operations within the glovebox do not exclude the presence of moderating material, but do prohibit operations in the presence of more than 10 L (2.6 gal) of free liquid.

The criticality controls will be the prohibition of performing operations in the presence of an unsafe amount of moderator, defined as greater than 10 L (2.6 gal) of moderating material, and monitoring of fissile mass of suspect matrices as the drums are being loaded. An additional assurance for criticality control in the PGS will be the low fissile loading in certain waste matrices (e.g., pieces or remnants of drums) with the need for high fissile masses in these matrices to achieve an unsafe condition .

The possibility exists for the fire suppression system to activate while fissile-bearing waste is present in the PGS; therefore, an administrative control will be put in place that will stop operations in the presence of an unsafe amount of moderator. If the fire suppression system activates, the free liquid will be absorbed before operations within the PGS are resumed. Fissile monitoring of suspect waste matrices will be completed in the glovebox. The FMM station will consist of a detector placed outside the glovebox. Suspect material will be put in a specimen container and placed in the fissile material monitor for monitoring. These controls will ensure that an unsafe amount of fissile material will not be disturbed in the presence of an unsafe amount of free moderating material.

The geometry of the glovebox does not easily lend itself to the formulation of an unsafe geometry that could lead to an increase in reactivity. The open area of the glovebox floor will disperse material rather than concentrate it. Additionally, the glovebox is not watertight so some localized shallow pools may form but it will not hold large quantities of water. The glovebox has an open end that extends into the RCS thus allowing water to flow back into the retrieval area in the event of the actuation of the fire suppression system. The fire suppression system is a mist type system.

Liquids in the waste may contain fissile material at undetermined concentrations. The current design of the PGS does not incorporate drip trays or collection receptacles for liquids. Preliminary plans dictate that any free liquids in the transfer cart or the PGS will be absorbed in place if the volume of the liquid is greater than 10 L (2.6 gal) or can be returned to the retrieval area provided the total volume is less than 10 L (2.6 gal).

The specimen container used in conjunction with the FMM will be designed such that its volume does not exceed 10 L (2.6 gal) or have design features (e.g., drain holes) that preclude greater than 10 L (2.6 gal) of free liquids accumulating inside.

6.5.3 Drum Waste Loading and Drum Loadout Stations

The final step in the process is to place the waste material that has been retrieved from the waste retrieval area, sorted and monitored, if needed, into waste drums for disposition (see Figure 8).

The most probable location to postulate a critical configuration is within the confines of a 55-gal drum. If certain types of material (e.g., filter media containing fissile material) were placed in a 55-gal drum without being monitored, the drum could be flooded and a critical configuration could be postulated. Waste forms (e.g., HEPA filter media) tend to form a more homogenous distribution of fissile material within a matrix that can have a wide range of void volume fractions. Additionally, overloaded waste drums associated with this waste form currently exist in aboveground storage. Computational models were evaluated (Sentieri 2002) consisting of PuO_2 dispersed within intact HEPA filters. These models confirm the reactive nature of this waste form with respect to criticality safety.

Monitoring and ensuring adherence to the drum fissile-loading limit of 380 g FGE per drum will provide a control for ensuring that a critical configuration does not form. Operational drum-loading limits will be set at 200 g FGE per drum. This is the current fissile-loading limit delineated in the *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria* (DOE-ID 2002). Drums meeting the 200 g FGE limit can be stored at the RWMC in accordance with the current RWMC drum storage requirements. The criticality administrative control limit is set at 380 g FGE per drum. Analysis[d] shows that an array of up to 500 drums in a 10 × 10 × 5-high configuration is critically safe. The estimated number of drums produced from this retrieval effort will be approximately 500.

Other waste forms require very large fissile masses to postulate the formation of a critical system. Matrices that comprise sludge material, soil, and some visually identifiable combustibles are expected to contain waste material combined with low fissile-gram quantities (e.g., personal protection equipment). The low level of fissile loading per drum is a result of the processes that produced these waste matrices. Historical assay data confirm low fissile loading in drums containing these materials. In addition, because of the nature of this waste, fissile material contained in these types of matrices would have to exist in homogeneous multiple-kilogram quantities before they would become a criticality safety concern, which is not credible. Therefore, matrices that have been determined to have low fissile loading because of their process origination (i.e., comprising sludge material, soil, and visually identifiable combustibles) will be loaded directly into waste drums without any fissile monitoring.

Whether or not waste forms need to be monitored can be approached by one of two methods:

1. The first method would be to dismiss the need for monitoring based on a qualitative argument, which would qualitatively dismiss the formation of a critical system based on historical process knowledge, the nature of the constituents comprising the waste form, or the form of the waste itself. The use of historical process knowledge can be used to dismiss the need to assay certain forms of waste before loading into a drum. Personal protective equipment will have very low fissile loading; therefore, this waste form does not need to be monitored before being placed into a drum. Additionally, plutonium is not homogeneously dispersed in plastics used for contamination control purposes; therefore, these plastics do not need to be fissile monitored before being placed in a waste drum.

   Using the constituents present in the waste form, as a basis for not monitoring the waste form, before placement into a waste drum is another valid approach. A good example of this would be the Series 745 sludge with constituents containing a large amount of chlorine in the form of various salts. Chlorine is a good neutronic absorber and increases the fissile mass necessary to achieve an unsafe condition.

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d. An internal report by J. W. Nielsen was completed in 2002, and is a criticality safety evaluation for finite arrays of drums containing up to 380 g of Pu-239 at RWMC.

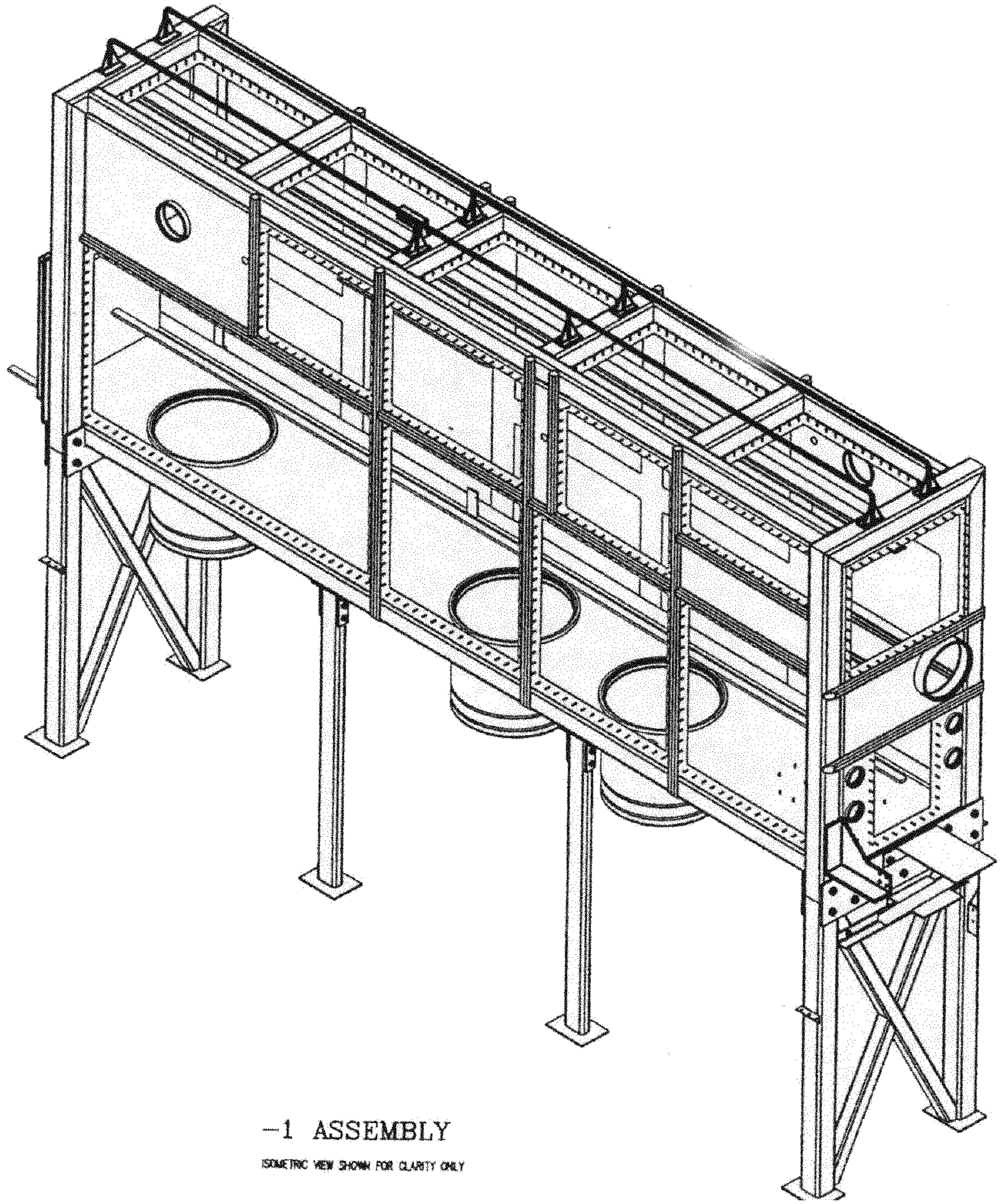

Figure 8. Isometric of glovebox and drum loadout for the OU 7-10 Glovebox Excavator Method Project.

An example of using the waste form itself as a reason for not monitoring the waste before loading in a drum would be drum remnants. These drum remnants would contain surface contamination of plutonium; therefore, very small plutonium masses would be expected in this waste form. Drum remnants from the dig area do not need to be monitored before loading.

2. The second method to dismiss the need for fissile monitoring a waste form is quantitatively by creating computational models of the specific waste forms to show the fissile masses necessary to achieve an unsafe condition. Because the majority of the waste expected in the dig area comprises sludge, soil, and some graphite, these three waste forms were evaluated using computational models to determine the levels at which unsafe conditions would occur. Expected waste matrices from process burial history are analyzed in the following sections.

6.5.4 Waste Materials

6.5.4.1 Waste Matrices Not Needing Fissile Monitoring. The forms and compositions of some of the waste matrices do not require fissile monitoring before placement into a waste drum. These matrices are discussed in the following subsections.

6.5.4.1.1 Sludges—The Series 74 sludges consist of first stage sludge (Series 741), second stage sludge (Series 742), organics (Series 743), special setups (Series 744), and salts (Series 745). A more complete description of these sludge forms can be found in the document, Acceptable Knowledge Document for INEEL Stored Transuranic Waste-Rocky Flats Plant Waste (WASTREN 1998). Historically, the fissile loading in the Series 741, 742, and 743 sludges and Series 745 salt matrices is very low. The Series 744 sludge matrix has a slightly higher fissile loading than the other four listed matrices. Of the 1,650 drums of Series 744 sludge currently in aboveground storage, 76 have been assayed with only four sludge drums being determined to be in excess of the 200 g fissile-loading limit. All four of these drums have less than 380 g FGE with assays of 219.9, 251.6, 307.5 and 350.2 respectively.

Series 741 sludge consists of immobilized materials generated from the first stage treatment operations in RFP Building 774. Aqueous liquids coming into the process originated from RFP Building 771 recovery operations. The aqueous waste was made basic with the addition of NaOH to precipitate out waste constituents including a small amount of plutonium oxides. This precipitate was filtered to create a sludge that was eventually mixed with Portland cement (WASTREN 1998). Approximately two waste drums of sludge were created from a tank of waste solution.

The first stage aqueous liquid waste was held in Raschig-ring filled transfer tanks in RFP Building 771 before transfer to RFP Building 774. Analytical samples were taken before transfer of the aqueous liquid waste from RFP Building 771 to Building 774 because the transfer was made into large critically unsafe geometry tanks in RFP Building 774. The unsafe geometry tanks in RFP Building 774 were limited to a total fissile mass loading of 200 g. Therefore, the amounts and transfers of fissile material to these tanks were tracked before shipment to ensure compliance with the 200-g fissile limit.

Series 742 sludge consisted of immobilized materials generated from the second-stage treatment operations in RFP Building 774. It underwent a similar process described for the Series 741 sludge. Historically these sludge matrices contained small amounts of plutonium. Therefore, these waste forms will not need to be assayed before the placement of this material into a drum. This is because of the likelihood of overloading a waste drum in excess of 200 g. If this loading was exceeded, it is not credible to load a drum with enough fissile material in this matrix to form an unsafe condition.

To bolster confidence in this approach, a set of computational models was developed to determine the fissile mass necessary to create an unsafe condition within these matrices. Both the Series 741 and 742 sludge matrices have a large amount of moisture; therefore, relatively substantial hydrogen content exists. Two approaches were developed. The first approach evaluated Series 741 sludge containing various concentrations of Pu-239 in the form of PuO_2 distributed homogeneously throughout an entire single waste drum fully loaded with Series 741 sludge. The composition of the sludge (Schuman and Tallman 1981) used is given in Appendix C. The model assumed full reflection around the entire drum with saturated soil, which is slightly more conservative than water reflection (see Table 8). The results of these cases are given in Table 9.

Table 9. Results from PuO_2 in Series 741 sludge within each waste drum.

PuO_2 in Series 741 Sludge (g/L)	Pu-239 per Drum (g)	H/Pu Ratio of System	$k_{eff} + 2\sigma$
5	914.1	3,306	0.485
10	1,828.2	1,653	0.648
15	2,742.3	827	0.884

As shown by the results given in Table 9, the system will remain subcritical even with a fissile loading of 2.7 kg of Pu-239 mass in a single drum. The fissile material was distributed through the drum in a homogeneous manner. Another model was evaluated in which the PuO_2 was distributed in a system of Series 741 sludge in the form of a sphere. For this model, 1,500 g of Pu-239, in the form of PuO_2, was distributed within the sludge material over increasing volumes within a sphere. The radius of the fissile material and sludge was increased to determine optimum conditions. The previous set of cases evaluated fissile concentration over a set volume. This model evaluates varying concentrations for a given fissile mass. The sphere of plutonium and sludge was fully reflected by saturated soil. The results from these cases are given in Table 10.

Table 10. Results from PuO_2 in Series 741 sludge in spherical form at optimum moderation.

Radius of PuO_2 and Series 741 sludge (cm)	Mass of Pu-239 Contained in Sphere (g)	H/Pu Ratio of System	$k_{eff} + 2\sigma$
10	1,500	40.7	0.609
15	1,500	137.5	0.794
20	1,500	325.9	0.889
25	1,500	636.4	0.890
30	1,500	1,099.7	0.821
35	1,500	1,746.3	0.716

As shown by the results in Table 10, a model containing 1,500 g of Pu-239 is subcritical in an optimum geometry at optimum moderation within the specific matrix and full reflection around the system. These results show that it is not credible that a criticality event associated with the Series 741 sludge matrix could occur for the expected fissile masses.

The composition of the Series 742 sludge is given in Appendix C, which shows that it is very similar to the Series 741 sludge (Schuman and Tallman 1981). The same arguments applied to justify not assaying the Series 741 sludge can be used to justify not assaying the Series 742 sludge before loading the waste in this matrix into a drum.

The Series 743 sludge waste matrix consisted of various types of organic liquid waste that were transferred to RFP Building 774 to be mixed with a synthetic calcium silicate to form a paste or grease-like substance. These organic waste liquids were primarily composed of oil and chlorinated solvents used in degreasing and machining operations in RFP Buildings 707 and 777. The composition of the mixture consisted of approximately 114 L (30 gal) of liquid organic waste to 45 kg of Micro-Cel E (i.e., synthetic calcium silicate).

Computational models were developed to determine the fissile mass necessary to create an unsafe condition within these matrices. The same methods used for the Series 741 sludge were used for the Series 743 sludge. The first models developed consisted of PuO_2 at various concentrations distributed homogeneously through an entire single waste drum of Series 743 sludge that was fully reflected on all sides with saturated soil.

The second set of models evaluated 1,500 g of Pu-239, in the form of the PuO_2 combined with Series 743 sludge in spherical form to determine most reactive concentrations. The composition of the Series 743 sludge consisted of approximately 114 L (30 gal) of oil (80%) and CCl_4 (20%) combined with approximately 45 kg of Micro-Cel E, a synthetic calcium silicate. The formulation for the Series 743 sludge, as it was modeled, can be found in the associated spreadsheets contained in Appendix B. Spherical models also were evaluated as fully reflected by saturated soil.

As shown by the results given in Table 11, the system will remain subcritical with a fissile loading of 3.6 kg of Pu-239 mass in a single drum.

Table 11. Results from PuO_2 in Series 743 organic setup sludge within each waste drum.

PuO_2 in Series 743 Sludge (g/L)	Mass of Pu-239 Contained in Drum (g)	H/Pu Ratio of System	$k_{eff} + 2\sigma$
5	914.1	5,018.5	0.147
10	1,828.2	2,509.3	0.270
15	2,742.3	1,672.8	0.373
20	3,656.4	1,254.6	0.460

As shown by the results in Table 12, a model containing 1,500 g of Pu-239 in an optimum geometry, at optimum moderation within the specific matrix, and full reflection around the system remains safely subcritical.

Table 12. Results from PuO_2 in Series 743 organic setup sludge in spherical form at optimum moderation.

Radius of PuO_2 and Series 743 sludge (cm)	Mass of Pu-239 Contained in Sphere (g)	H/Pu Ratio of System	$k_{eff} + 2\sigma$
10	1,500	61.8	0.644
15	1,500	208.6	0.707
20	1,500	494.5	0.638
25	1,500	965.8	0.490
30	1,500	1,668.9	0.366
35	1,500	2,650.3	0.261

These results show that it is not credible that a criticality event could occur, associated with the Series 743 sludge matrix, for the expected fissile masses.

Series 744 sludge consisted of special setups from operations that did not have a direct feed into the waste processing buildings or the waste produced from special operations that were not chemically compatible (WASTREN 1998) with the waste process stream in RFP Building 774. The liquids included mostly complexing agents, strong acids, and strong bases. The liquids were transferred in polyethylene bottles to a glovebox. The liquid was then transferred to a tank at which time acid waste was neutralized. Basic solution was left untreated. A mixture of approximately 93 to 112 kg of Portland cement and 37 to 56 kg of insulation cement was combined with 80 to 100 L (21 to 26 gal) of the basic waste or neutralized liquid in a 55-gal drum. The drum was then placed onto a drum roller for mixing.

The combination of the 80 to 100 L (21 to 26 gal) of Series 744 waste solution with the cements would yield compositions similar to those modeled for the Series 741 and 743 sludges. Therefore, similar fissile masses would be safe for the Series 744 sludge composition as those shown safe for the Series 741 and 743 sludges. Therefore, the Series 744 sludge does not need to be fissile monitored before placement into a drum.

Series 745 sludge consisted of evaporator salts. The low fissile mass, low hydrogen content because of the low moisture content, and chemical composition of this sludge type, indicate this sludge matrix will be less reactive than those previously evaluated. No criticality concerns associated with this sludge form have been identified and this waste does not need to be fissile monitored before placement into a waste drum.

After the sludge type waste has been loaded into a drum, the drum will be placed into lag storage until it can be assayed to ensure compliance with the fissile drum-loading limits.

6.5.4.1.2 Soil—Anderson (2002) estimates that over 50% of the waste zone within the waste retrieval area is composed of soil. As the drums within the waste zone deteriorated, the waste material, along with its fissile components, became intermixed with the surrounding soil. Additionally, in the process of recovering the waste material, the excavator will tend to mix waste material with the soil. To expedite the waste retrieval and repackaging process, the soil recovered will be placed directly into a waste drum without being fissile assayed while loading. After the waste has been loaded into a drum, the drum will be placed into lag storage until it can be assayed to ensure compliance with the fissile drum-loading limits.

Each excavator load will be placed onto a lined transfer cart and brought into the PGS. Operational personnel then will sort through the cart to remove those items identified for fissile monitoring because of the potential higher fissile loading associated with these certain matrices. Other waste forms that have been identified to not need fissile monitoring will be loaded directly into a waste drum. The remaining soil contained in the liner will be transferred directly into a waste drum. Once a waste drum is full, it will be decontaminated, brought out of the drum-out tent, placed into lag storage, and eventually assayed for fissile content.

To address this issue, computational models were developed to determine the fissile mass necessary to create an unsafe condition within a soil matrix. The same approach used in the sludge models was used for the soil models. The first approach evaluated soil containing various concentrations of Pu-239 in the form of PuO_2 distributed homogeneously through a fully loaded soil waste drum. The composition of the soil (Callow et al. 1991) used is given in Appendix C (Tables C-1 through C-3). The soil was modeled with the 40% volume fraction within the soil filled with water, which is fully saturated soil and is very conservative. The model assumed full reflection around the entire drum with saturated soil. The results of these cases are given in Table 13.

Table 13. Results from PuO_2 in soil within each waste drum.

PuO_2 in Soil (g/L)	Mass of Pu-239 Contained in Drum (g)	H/Pu Ratio of System	$k_{eff} + 2\sigma$
5	914.1	2534	0.599
10	1828.2	1267	0.851
13	2376.7	974	0.941
15	2742.3	845	0.987

As shown by the results given in Table 13, the system will remain subcritical with a fissile loading of 2.3 kg of Pu-239 mass in a single drum. This model assumed the fissile material was distributed through the drum in a homogeneous manner.

Another model was evaluated in which the PuO_2 was distributed in a system of soil in the form of a sphere. For this model, 1,500 g of Pu-239, in the form of PuO_2, was distributed within the saturated soil material over increasing volumes within the sphere. The radius of the fissile material and soil was increased to determine the point of optimum moderation. The previous set of cases evaluated fissile concentration over a set volume. This model evaluates varying concentration for a given fissile mass. The sphere of plutonium and saturated soil mixture was fully reflected by saturated soil. The results from these cases are given in Table 14.

As shown by the results in Table 14, the system is subcritical with a model containing 1,500 g of Pu-239 in an optimum geometry, at optimum moderation within the specific matrix, and full reflection around the system. These results show it is not credible that a criticality event could occur within the soil matrix for the expected fissile masses. The composition of the soil is given in Appendix C. It cannot be ruled out as impossible that a drum of unassayed soil will exceed the drum fissile loading limit of 380 g FGE. However, these calculations show that the fissile mass necessary to achieve an unsafe condition is very large in comparison to the expected fissile mass within the waste retrieval area and would require homogeneous distribution of the fissile material and full flooding.

Table 14. Results from PuO_2 in soil in spherical form at optimum moderation.

Radius of PuO_2 and Soil (cm)	Mass of Pu-239 Contained in Sphere (g)	H/Pu Ratio of System	$k_{eff} + 2\sigma$
10	1,500	31.2	0.566
15	1,500	105.3	0.753
20	1,500	249.6	0.883
25	1,500	487.7	0.934
30	1,500	842.7	0.910
35	1,500	1,338.2	0.840

6.5.4.1.3 Other Waste Materials Not Needing Fissile Monitoring Before Drum Loading**—**Other waste forms that do not need to be fissile monitored before being placed into waste drums are discussed below:

- **Drum remnants**—Drum remnants do not need fissile monitoring before being loaded into a waste drum. The expected fissile material associated with this waste form will exist as surface contamination. Therefore, these waste forms should not contribute much fissile mass to the total drum inventory.

- **Personal protective equipment**—Waste matrices that can be identified as personal protective equipment do not need to be fissile monitored before being loaded into a waste drum. The expected fissile mass associated with this waste form should be at or slightly above contamination levels. Aboveground assaying of this waste form has yielded no drums in excess of the 200 g fissile drum-loading limit.

- **Plastic materials used in contamination control—**Waste matrices that can be identified as plastic sheets used for contamination control purposes do not need to be fissile monitored. This matrix should have only surface contamination and not contain high fissile material concentrations.

All drums will be placed into lag storage until the drums can be assayed for fissile content. The lag storage area will include spacing between the unassayed drums to ensure a subcritical system is maintained. The spacing between unassayed drums will be controlled as 41-cm (16.0-in.) edge-to-edge spacing in a single planar array of drums.

6.5.4.2 Waste Matrices That Need Fissile Monitoring. The following subsections discuss those matrices identified as needing fissile monitoring before being placed into a waste drum. The fissile loading associated with the monitored amount will be tracked and added to the amount of total fissile inventory in the drum. This will help to ensure that the single drum fissile-loading limit of 380 g FGE is met.

6.5.4.2.1 Graphite**—**Discussions with past RFP operational personnel indicate that the graphite waste matrix could contain a higher fissile loading than most of the other waste forms. Graphite was used as a mold material into which various parts were cast. Approximately 50% of the aboveground stored waste drums of this item description code (IDC) have been fissile assayed. This fissile assaying has determined that three of these drums contain more than 200 g but less than 380 g FGE per drum.

Some of the RFP graphite molds were used to form classified shapes. Plutonium recovery operations for these classified molds involved crushing the molds completely followed by a leaching process to recover the plutonium. Once the molds were crushed into small particles the plutonium leaching recovery process was quite efficient.

Other RFP graphite molds involved the creation of plutonium ingots. These ingots were turned into parts by various operational processes. For the most part, these types of graphite molds were not classified. A surface scarfing process was employed to recover as much plutonium as possible from these types of molds. Once the plutonium was scarfed from an unclassified mold, it was reused if possible or placed into a drum for eventual disposal at the INEEL.

In some instances, the scarfing process caused the molds to break apart, thus rendering them unusable. These chunks were disposed of as waste. In some cases the molds themselves had surface defects allowing molten plutonium to penetrate fissures and cracks within the mold. In these cases the scarfing process would not be able to recover these small plutonium deposits within the mold fissures. Therefore, the molds were a reasonable candidate for higher plutonium holdup. Because of the potential for holdup of plutonium, graphite found in the waste retrieval area should be fissile monitored before being placed into waste drums.

The types of graphite that should be fissile monitored include intact molds, an intact bag full of intact molds or large pieces of molds, or a large cache of larger graphite pieces dumped into the transfer cart from the waste retrieval area. Small pieces of graphite (measuring more than approximately 2 in. in diameter), if found intermixed in the soil, do not need to be fissile monitored as long as they are not part of a large grouping of graphite that has been brought into the PGS. Implementation of these criteria will be defined more thoroughly as the operational procedures are finalized. The intent is to fissile monitor the larger pieces that may contain plutonium hold up rather than going through the waste to ensure every single miniscule piece of graphite has been fissile assayed.

Probe-hole data indicates that one localized area in the retrieval area (designated as P-920) could contain from 547g of plutonium (unlikely according to the final documented safety analysis) up to approximately 2,200 g of plutonium (extremely unlikely according to the final documented safety analysis). Records indicate that the area reportedly contains graphite waste. Calculational models evaluated in a previous study (Sentieri 2002) demonstrate that a large fissile mass is necessary to achieve an unsafe condition in a graphite waste system. It was shown in the previous study (Sentieri 2002) that a spherical system of 1,000 g of weapons grade plutonium, in the form of plutonium oxide combined with water, would remain safely subcritical. The amount of water present corresponds to the void volume fraction of the system. This volume fraction was modeled from 10 to 40% with 40% being the most conservative. This value was chosen as the limit for the volume fraction because volume fractions beyond this level begin to encroach on solution systems. Such systems are not credible for the waste forms and chemical compositions expected. The system was fully reflected with fully saturated soil thus decreasing neutron leakage. These calculational models are extremely conservative yet still yield subcritical systems. The introduction of the data relating to P-920 does not invalidate the control scheme that is being implemented in the PGS. It is extremely unlikely that such a large fissile mass is present in the area, but if such a mass is present, then it would need to be fully moderated and distributed in near idealized conditions to achieve an unsafe condition.

Though these calculational models demonstrate subcriticality for rather large fissile masses, suspect matrices that could contain higher fissile loading should be fissile monitored before being placed into a waste drum to prevent the creation of an overloaded drum (i.e., FGE equal to or higher than 380 g per drum).

***6.5.4.2.2 Magnesium Oxide*—**Current fissile assay data indicate that six drums contain fissile loading in excess of 380 g FGE per drum in current aboveground storage. The IDC associated with each of these drums is 393. This IDC is identified as sand, slag, and crucible heels. Historical data indicate that no MgO is expected in the waste retrieval area. However, the historical burial records cannot be relied on with total confidence.

This particular IDC contained waste material consisting of MgO crucibles from the electro-refining process used in plutonium recovery operations. Sand was used in the process and thus resulted as a waste product. The slag was produced as the plutonium concentrated in the crucible and separated from impurities.

Intact containers of MgO material should be fissile monitored before being placed in a waste drum. Assay data associated with this type of aboveground stored waste indicate that this waste form has an increased probability higher fissile loading. This increases the chances of overloading a waste drum if this material is not monitored.

Calculational models were evaluated in the Sentieri (2002) study that demonstrate the fissile mass necessary to achieve an unsafe condition in a small MgO system. It was shown that a spherical system of MgO and 1,500 g of weapons grade plutonium, in the form of plutonium oxide combined with water, would remain safely subcritical. The amount of water present corresponded to the void volume fraction of the system, which was modeled as 50% water or less. The system was fully reflected with fully saturated soil, thus decreasing neutron leakage. These calculational models are extremely conservative yet still yield subcritical systems.

Even though these calculational models demonstrate subcriticality for rather large fissile masses, suspect matrices that could contain higher fissile loading should be fissile monitored before placement in a waste drum to prevent the creation of an overloaded drum (i.e., FGE equal to or higher than 380 g per drum).

***6.5.4.2.3 Intact High-Efficiency Particulate Air (HEPA) Filters, HEPA Filter Media, and Material Not Distinguishable from HEPA Filter Media*—**Current fissile assay data from retrievably stored inventory at RWMC indicate that 23 drums exist that contain filter media with fissile loading in excess of 380 g FGE per drum, with one exceeding 1,500 g FGE. The IDC associated with each of these drums is 376. This IDC is identified as filter media. Historical data indicate that no filter media is expected in the waste retrieval area. However, the historical burial records cannot be relied on with total confidence.

The physical nature of filter media and intact filters lends itself to more optimal conditions, unless the filter media or intact filter is compressed or degraded, with regard to creating a critical configuration. This waste form consists of material with a low physical density, a high void volume fraction, a more homogenous distribution of fissile material, and a history of high fissile assaying. The combination of these factors increases the probability for the formation of a postulated critical configuration in a fully moderated situation. Moderator control (not exclusion) will be implemented in this operation. The disturbance of waste material in the presence of an unsafe amount of free liquid (i.e., more than 10 L (2.6 gal)) will be prohibited until the free liquid is absorbed. Therefore, intact HEPA filters, HEPA filter media, and waste materials that cannot be distinguished from HEPA filter media, will be fissile monitored in the glovebox FMM system before being placed in a waste drum.

6.5.4.2.4 Containerized Unknown Waste Materials with Potential of Having Unsafe Plutonium Masses—Retrieved unidentified containerized waste forms with potential for having unsafe masses of plutonium will need to be fissile monitored before being placed in a waste drum. The evaluation considered various sources that could be associated with unsafe quantities of fissile masses. Containerized unknowns need to be grouped into the category of items having the potential to introduce an unsafe mass into a waste drum. In the presence of sufficient moderating material this unsafe mass creates a postulated scenario. Therefore, containerized unknowns will need to be fissile monitored to determine whether fissile material is present.

6.6 Drum Lag Storage

6.6.1 Drum Lag Storage Area

A limit is required for handling drums that have not been assayed for fissile mass. This limit will ensure that waste drums will be separated from one another by a 16-in. edge-to-edge separation (Woods and Neeley 2001) in a planar array. These drums then will be assayed for fissile content. If the fissile loading meets the INEEL WAC (DOE-ID 2002) of 200 g FGE per drum, these drums can be stored in normal approved storage configurations. If the drums do not meet the WAC when assayed, they will be placed back into lag storage and isolated until they can be repackaged or dispositioned.

Drums with FGE loading between 200 and 380 g can be safely stored in a 10 × 10 × 5-high array as shown in Nielsen (see footnote e). Drums in excess of 380 g FGE are required to be handled in accordance with requirements listed in the RWMC documented safety analysis. This involves spacing and overpacking to prevent water intrusion.

Drums that have been assayed and confirmed to meet the INEEL WAC will remain safely subcritical in any configuration. The drums in the lag storage area will contain waste materials that have not been assayed using whole-drum counting techniques. Assaying of the drums is not required before placement of the drums into lag storage. The storage configuration has been shown to be safe for drums containing up to 1,500 g FGE per drum in a single planar array stored with the 16-in. edge-to-edge drum spacing requirements. This high fissile mass per drum (i.e., greater than 1,500 g FGE) required for criticality to occur, is deemed not credible.

6.7 Samples

Current sample plans call for the collection of soil and sludge materials to accomplish confirmatory analyses relating to applicable characterization requirements. The samples will be collected in 250-mL polyethylene bottles, which equates to approximately 370 g of soil, assuming a soil density of 1.46 g/cm^3. The types of waste matrices being sampled (e.g., soil and sludge), and the expected amounts of fissile mass in these sample sizes, indicate no credible criticality scenarios. However, if the sampling strategy changes, then criticality controls on the samples will be implemented through either a volumetric or mass control limitation.

7. DESIGN FEATURES AND ADMINISTRATIVELY CONTROLLED LIMITS AND REQUIREMENTS

The following engineering and administrative controls have been identified in this CSE. These controls are required to ensure criticality safety during the Stage II operations.

7.1 Engineering Controls

The three engineering controls associated with criticality for the OU 7-10 Glovebox Excavator Method Project are listed below:

- The height of the transfer cart was evaluated at a height up to 8.0 in. The dimension was used in this report and therefore is a dimension of importance to criticality safety. The height of the transfer cart is designed to be less than 20.32 cm (8.0 in.) with an inside length and width not exceeding 127 cm (50 in.) by 157.48 cm (62 in.).

- The drum-sizing tray will be designed such that it will ensure that liquid cannot collect above a height of 20.32 cm (8.0 in.) with an inside length and width not exceeding 127 cm (50 in.) by 157.48 cm (62 in.).

- The volume of the specimen container will be limited to no more than 10 L (2.6 gal)or drain holes will be placed in the 19-L (5-gal) specimen container that will ensure that no more than 10 L (2.6 gal)of liquid can collect in the 19-L (5-gal) specimen container.

7.2 Administrative Controls

This CSE provides administrative controls for the safe removal, handling, and storage of fissile material. These controls ensure favorable geometry and mass controls that will reduce the likelihood for a criticality accident. The administrative controls for the project are discussed below:

- **Fissile monitoring—**

  - Waste matrices not needing fissile monitoring before placement in a drum include sludge, soil, visibly identifiable combustibles such as personal protective equipment and plastics that were used for contamination control purposes, and drum remnants.

  - Waste matrices needing fissile monitoring before placement in a drum are waste materials of concern (e.g., filter media, material not distinguishable from intact filters, intact graphite molds, pieces of graphite molds bigger than approximately 2 in. in diameter, intact containers of MgO, and other containerized unknowns that could potentially contain unsafe quantities of fissile material) that must be fissile monitored as drums are being loaded to ensure compliance with the drum fissile-loading limits of 200 g FGE per drum and not exceeding the criticality administrative control limit of 380 g FGE per drum.

- **Deluge system**—Activation of the deluge system, during waste retrieval operations, that introduces more than 10 L (2.6) of free liquid requires that all disturbance of material in the waste retrieval area will stop. Operations may resume after the free liquid in the excavation area is reduced to less than 10 L (2.6 gal).

- **Free liquid in retrieval area**—If 10 L (2.6 gal) or more of free liquid is encountered during retrieval operations, then all disturbance of material in the waste retrieval area will stop. Operations may resume after the free liquid has been absorbed.

- **Free liquid in the PGS**—If more than 10 L (2.6 gal) of free liquid is present or introduced into the PGS because of activation of the fire suppression system or waste zone material-handling operations, all waste zone material-handling operations in the PGS will stop. Waste zone material handling operations may resume after less than 10 L (2.6 gal) of free liquid is present within the PGS.

- **Fissile-loading limit**—The drum fissile loading from monitored waste should not exceed 200 g FGE.

- **Criticality alarm system**—A criticality alarm system will be required and will provide coverage for the waste retrieval area and the PGS during retrieval and packaging operations.

- **Fissile assay**—Drums that have not been fissile assayed must be spaced with a 16-in. edge-to-edge separation from other drums in a single planar array when placed in lag storage (Woods and Neeley 2001).

- **Safety commitments**—Currently, no safety commitments associated with the proposed sampling activities are anticipated. This is because of the type of waste matrices being sampled (e.g., soil and sludge) and the low expected fissile masses in these waste matrices. However, if the sampling strategy changes, then criticality controls on the samples will be implemented through either a volumetric or mass control limitation.

8. SUMMARY AND CONCLUSIONS

The criticality potential of the OU 7-10 Glovebox Excavator Method Project and the necessary associated controls have been analyzed in this CSE. The criticality potential in the waste retrieval area, the PGS, and the drum lag storage area were evaluated. The probability of criticality has been deemed extremely unlikely because of the expected forms of waste in which the fissile materials are distributed. In addition, achieving a critical system is physically impossible without the presence of sufficient moderator. Controls will be implemented to prohibit operations in the presence of an unsafe amount of free liquid, defined as more than 10 L (2.6 gal), which could be mixed with the fissile material in the various waste matrices.

Waste will be categorized into two groups, which are (1) waste that does not require fissile monitoring before placement in a drum and (2) waste that does require fissile monitoring before being placed in a drum. This is based on the form and distribution of fissile material in the waste along with the historical inventory data associated with the expected waste matrices contained in the dig area. In addition, the results from the assay of drums currently in retrievable storage at the RWMC support this conclusion. The matrices include waste that will not require monitoring before being loaded into a drum, such as the following:

- Soils
- Sludge material
- Plastics used for contamination control purposes
- Drum remnants.

Currently, other materials (e.g., cemented HEPA filters, intact HEPA filters, HEPA filter media, materials that are indistinguishable from HEPA filter media, graphite molds, chunks of graphite molds larger than approximately 2 in. in diameter, intact containers of MgO, and unknown containerized waste that has the potential to contain an unsafe amount of plutonium) will be fissile monitored before being placed in a waste drum. From an operational standpoint, not creating overloaded drums is highly desirable because of the difficulty associated with repackaging operations. This is especially true in waste matrices that, if overloaded with fissile material, would lend themselves to the formation of a critical system more readily if fully moderated.

The development of this list is based on assay data obtained from overloaded drums currently in retrievable storage at the RWMC (i.e., drums that are categorized as overloaded and have a fissile drum loading in excess of 380 g FGE). If new developments occur relating to the drums currently categorized as overloaded in aboveground storage, a justification could be developed to remove these waste matrices from the list of material to be monitored.

An example of this might be MgO, assuming that (1) new assaying processes are employed to reevaluate the overloaded MgO drums and (2) an evaluation of the results of these new assays shows that the actual fissile loading in all of the MgO drums is within the acceptance criteria for fissile drum loading. A justification could be developed, as a result of this scenario, to have this matrix removed from the list of waste materials needing to be fissile monitored before loading.

Some packaging without monitoring, as described above, will be allowed because of the expected low fissile loading and the composition of the specific waste matrices. Fissile monitoring is not required because of the low expected fissile masses of these waste matrices and the unrealistic, high fissile masses required for criticality to occur in such waste matrices. However, all drums will be placed in lag storage where they will be isolated until an assay of the fissile content of the drums can be determined. After these drums have been determined to be in compliance with the fissile loading limits, they can be moved to an authorized drum storage array.

In addition, a criticality alarm system at the project site will provide coverage to mitigate the consequences of a criticality accident for both the waste retrieval area and the PGS.

The types of waste matrices expected to be retrieved and repackaged during project activities lead to the conclusion that the formation of a critical system will be a very low-probability event. However, a criticality scenario cannot be dismissed as incredible within the waste retrieval area and PGS because controls do not exist on the amount of fissile material present. Controls will be implemented prohibiting the disturbance of fissile masses in the presence of an unsafe amount of moderating material, in addition to fissile monitoring controls on certain waste types within the PGS to address the postulated criticality scenarios.

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